THE COMPARISON OF SUPPLEMENTS FOR YOUNG CALVES GRAZING AUTUMN PASTURE

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ABSTRACT

Thirty two autumn-born calves (sixteen bull and sixteen heifer calves) were used to compared the effects of alternative supplements on performance, health, herbage intake and feed efficiency of young calves.

1. Four bull and four heifer calves in each of four blocks,which had previously received milk ad libitum,were randomly allocated to each of the four treatments at 5-6 weeks of age. The supplements of liquid milk, dry milk and concentrates were calculated to provide 11.28 MJME metabolisable energy (ME) (for ruminants) and 175 g crude protein (CP) daily and were fed for 5 weeks. Supplements were offered once a day and amounts eaten were measured. The control group was weaned directly onto autumn pasture.

2. Calves were grazed in the same paddocks,predominantly ryegrass and white clover,divided into four equal areas by two electric wires. Individual paddocks were used in rotation for 4-5 days and calves offered a daily herbage allowance of approximately 60 g DM per kg liveweight. After the experimental period the calves were grazed on pasture together in two mobs, bulls in one and heifer calves in the other,and liveweights measured until about 33 weeks of age.

3. The DM intake of supplement and herbage by individaul calves were estimated indirectly using faecal markers (Chromic oxide and Polyethylene glycol).

4. Calf growth rates at various stages were measured. Feeding of supplements significantly ($P<0.001$) increased the liveweight gains of young calves grazing autumn pasture (control 257.1 g/d). Among the supplemented calves, calves receiving liquid milk had a significantly ($P<0.05$) higher liveweight gain (653.6 g/d) than those supplemented with soya bean concentrate (507.1 g/d) and dry milk (473.5 g/d).

Liveweight gain of calves after the supplemental period (10-33 weeks of age) were not significantly different between treatment groups.

5. There was no significant ($P<0.05$) difference between the liveweights of supplemented and non supplemented calves at 33 weeks of age but that for calves given the dry milk supplement was significantly ($P<0.05$) lower than those for the other supplemented groups.

6. All supplements significantly ($P<0.001$) depressed herbage DM intake of young calves. The depression of herbage DM intake per unit of supplement DM intake (substitution rate) for calves given dry milk supplement was significantly higher than those for calves consuming soya bean and liquid milk supplements. Total DM or OM intakes (g/d) of calves with soya bean supplement were significantly higher than for the other groups whereas there was no significant difference between those for milk supplements (dry and liquid milk supplements) and the non-supplemented calves.

7. Liveweight gain of calves during the supplemental period (5-10 weeks of age) were positively correlated ($r=0.76$) to the ratio of ME to CP intake (KJME/gCP) and amount of supplements DM intake ($r=0.65$).

8 The ME in rations containing milk supplements were estimated to have been used with greater efficiency for growth (K_g) than that from the soya bean concentrate or herbage diet.

9 A number of unexplained complaints (eg. red urine,hard faeces and swelling neck) were found in calves fed with dry milk supplement.

10 The use of markers (Chromic oxide and Polyethylene glycol) to estimate food intakes of calves has potential as judged by the results of this experiment.

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INTRODUCTION

Rearing calves on pasture has major advantages in terms of reduced housing and rearing costs. The high quality pasture generally grown in New Zealand means that it can form a significant increasingly dietary constituent for the calf from 3 or 4 weeks of age onwards (McMeekan, 1956, cited by Gleeson, 1971). Opinions differ however as to the age at which pasture should become the sole feed for calves. On the one hand it has commonly been shown that calves may consume significant amounts of pasture from 3 weeks of age and they can be successfully weaned onto pasture alone at 8 weeks of age (McMeekan,1954). In contrast Alder and Chambers (1958) suggested that calves should not be weaned until 13-16 weeks in order to get maximum liveweight gains.

Up to a liveweight of 70 kg the dry matter consumption of liquid feeds is greater than from solid feeds. Thereafter,calves can consume more of a solid than a liquid feed (Roy,1980). Clearly the timing of the change from a liquid to a solid feed is important.

The consumption of solid feeds,which are generally cheaper and involve less labour for feeding than liquid feeds, may be encouraged by restricting the level of milk feeding. Thus there is normally conflict between the desire for an early and complete transfer onto solid feeds(especially pasture) and the high performance of calves receiving higher levels of milk or liquid milk substitutes. In one compromise system,which has evolved in New Zealand, grazing calves are weaned off a low level of milk (4-5 l/d) onto concentrates at 5-6 weeks of age and then given grass alone from 10-12 weeks of age (Khouri et al, 1967; Khouri, 1969). However,this system may give poor results because of carry-over effects of lower liveweight at the time of weaning (Everett, 1972; Reardon and Everett, 1972). Early growth rates,particularly during the period from birth to four weeks of age,is critical to the successful

rearing of calves (Davey, 1974).

It was found that after calves were weaned off milk at an early age (5 weeks of age), concentrate supplemented calves had a higher liveweight gain than those given grass only in both indoor fed (Byford,1974) and grazing calves (Gleeson, 1971).

All of the methods discussed above involve restricted levels of milk feeding in early life and, as mentioned above, calves will show less than maximum growth rates prior to weaning. "Self-feeding" methods (ad libitum suckling) using whole milk (and/or stored colostrum or acidified milk Swannack(1983) have been designed to give high growth rates together with group feeding (low labour) advantages. This system "best" meets the requirements of the calf but might be expected to create problems with regard to inducing calves to eat solid foods in order to maintain growth rates once milk feeding ceases.

The main questions addressed in this study relate to various management alternatives for feeding autumn-born calves which have been fed high levels of milk up until 5-6 weeks of age (about 65 kg liveweight),as follow:

(1) Can the calves be directly weaning onto pasture ,and especially autumn pasture? It is worth noting that some evidence suggests that the digestibility and/or metabolisability of autumn pasture may be inferior to that of spring pasture (Beever et al,1978) (control treatment).

(2) Do calves require a period on lower levels of milk ? This would be expected to maintain growth rates and encourage consumption of grass (liquid milk treatment).

(3) Can milk be fed "dry" as part of a concentrate mix ? This system should involve less labour but the feeding value may be different from liquid milk because it would be expected to be digested in the rumen rather than the abomasum and intestine (Ørskov,1982) (powder milk treatment).

(4) How does a commercial concentrate supplement (containing soya bean protein) compare with milk as a supplement ? This system is perhaps the most widely used method on commercial dairy farms (soya bean concentrate treatment).

In this experiment supplements of liquid milk, dry milk and concentrates were fed at approximately equal energy and protein levels and the performance and health of calves measured. In addition estimates of their herbage intake were made using marker techniques and comparisons made of feed efficiency values.

CHAPTER 1

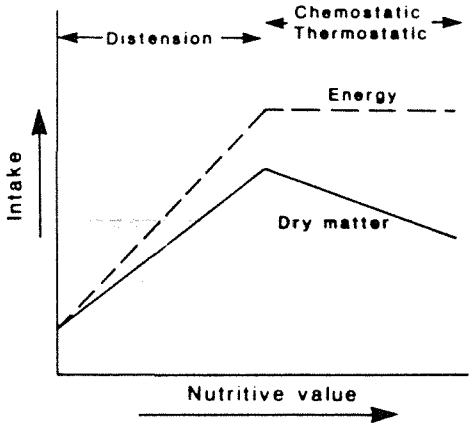
LITERATURE REVIEW

1.1 CONTROL OF VOLUNTARY INTAKE AND FACTORS AFFECTING FOOD INTAKE IN CALVES

1.1.1 Control of voluntary intake in the young ruminant

Many different factors have an influence on the intake of young ruminants but there are two important mechanisms, physical control and metabolic control, which have dominant effects. The role of physical control has been reviewed by Balch and Campling (1962), Campling (1970) and Conrad (1966) and that of metabolic control by Baile and Mayer (1970) and Baumgardt (1970).

Fig. 1.1 Probable relationships between food nutritive value and food intake controlling mechanism. (From Montgomery and Baumgardt 1965a)



The integration of these two mechanisms has been summarized in a model proposed by Montgomery and Baumgardt (1965a, see Figure 1.1). In this model the intake of low nutritive value foods are usually limited by rumen load whereas with the high nutritive value foods, energy demand limits food intake. Several authors have suggested that these mechanisms apply during the post-weaning period in lambs (Owen, Davies and Ridgeman, 1969b; Andrews, Kay and Ørskov, 1969; Andrews and

Ørskov, 1970) and in calves Kay, MacLeod and McLaren, 1970; Kay, MacLeod and Andrews, 1972; Kang and Leibholz, 1973). However, for grazing animals, the complication of the grazing process means that grazing skill or grazing behaviour is another factor which may limit feed intake. In the young ruminant,still receiving milk, these oropharygeal factors associated with the development of eating behaviour may also control the initial development of solid feed intake (Hodgson, 1971d).

The nervous system, most probably the hypothalamus, appears to play an important role in the control of feed intake. Chemical and electrical stimulation of the lateral hypothalamus has been demonstrated in sheep and goats to result in an increased feed intake (Meijs, 1981). Nervous signals, hormone levels and some blood metobolite concentrations may play important role in stimulating the hypothalamus.

Some of these important concepts are discussed in more detail in sections below.

1.1.1.1 Physical control

Ruminants being fed bulky feed may stop eating before they have consumed sufficient nutrients to achieve their genetic potential for production (Campling, 1970; Bines, 1971). The capacity of the alimentary tract, especially the reticulo-rumen may set a limitation on the animal's ability to ingest in this situation. Besides the capacity of the alimentary tract, the passage rate of digesta may also have an influence on voluntary feed consumption over a prolonged period of time (Hodgson, 1971b,e).

(1) The capacity of the alimentary tract

Intra-ruminal addition of food caused an immediate decrease in oral food intake while animals can be encouraged to eat for much longer than normal by removing the swallowed feed from the rumen (Campling, 1970). In young calves immediately

after weaning, the response was somewhat different from adult ruminants. Hodgson (1971d) found that the addition of food material resulted in a depression in dry matter intake which was greater than the increase in dry matter intake following the removal of digesta. It was postulated that the intake of solid feed after weaning is limited primarily by oropharygeal factors, and not by the fill of the digestive tract, or by metabolic factors. In calves weaned at 5 weeks of age, the response in intake to artificial changes in the quantity of rumen digesta increased significantly with age and reached or exceeded the 'adult' level within 4-6 weeks from weaning (Hodgson, 1971d).

(2) The rate of digesta passage

The passage of digesta from the reticulo-rumen depends on the rate of break down by the combined action of microbial fermentation and mechanical activity of the gut, including chewing during eating, rumination and muscular contractions of the gut (Campling, 1970). The rate of enzymic digestion by rumen microbes is closely related to the chemical composition of the feed (Bines, 1971). In the grazing animal, intake usually increases with organic matter digestibility over the range from 50 to 80% (Hodgson, 1975a). Such an increase in intake is likely to be due to an increased passage rate rather than an increase in reticulo-rumen size since rumen fill remains relatively constant(Meijs, 1981). Apart from digestibility, rate of passage depends on saliva production, rumen pH and on physical structure of the feed (long against ground roughages). Large amounts of concentrates intensify acid production in the rumen and reduce saliva flow, resulting in a decrease in rumen pH which affects cellulolytic activity, rate of passage and intake of roughages (Balch and Campling, 1969; Baile and Forbes, 1974). Presenting the ruminant with ground roughage, that is in a physical form in which the roughage can readily pass the reticulo-omasal orifice, leads to a higher voluntary intake than when the same roughage is offered in the long form (Campling, 1970). This finding provides support for the concept of physical limitation of

roughage intake imposed by the small size of the reticulo-omasal orifice.

1.1.1.2 Metabolic control

When concentrates make up a large proportion of the diet, factors other than the capacity of the alimentary tract and rate of passage of undigested feed residues, determine intake. Metabolic control of feed intake is in fact a mechanism to keep a balance between the requirements for, and the supply of nutrients, particularly energy. The mechanisms which may be involved are the chemostatic,lipostatic and thermostatic mechanisms.

(1) Chemostatic mechanisms

Ruminants offered mixed forage/concentrate or pure concentrate diets of high nutrient concentration do not eat to a limiting level of rumen fill at the end of the meal (Bines, 1971). As the digestible energy concentration of a diet increases above a certain level, food intake will decrease such that digestible intake is maintained at the level determined by the energy requirements of the animal. The digestible energy concentration at which this occurs depends on the energy requirement and hence on the physiological state of the animal (Bines, 1971). Volatile fatty acids, the main products of energy digestion in ruminants, are considered to be the food intake regulator for short term control (Baile and Mayer, 1970; Baile and Forbes, 1974).

Food intake decreased as the result of infusion of acetate ,propionate and lactate into the rumen of cattle and sheep whereas the result with butyrate addition were more variable (Bines, 1971; Baile and Forbes, 1974).

(2) Lipostatic control

Lipostatic control is considered to be responsible for long term regulation of energy balance. The size of the fat reserve in the body might be the best indicator of energy status of the animals. When animals are too thin in a certain situation, they will try to increase feed intake and build up some fat reserves. The level of plasma free fatty acid may serve as a signal for feed regulation. After calving a high level of plasma free fatty acids from adipose tissue corresponded to low intake (Journet and Remond, 1976). However,body fat levels are low in young ruminants so this factor is unlikely to be as important as is in mature cattle.

(3) Thermostatic control

In a cold environment, the feed intake of ruminants increased; in a hot environment, the feed intake decreased (Jones, 1972; Bines, 1976). There may be temperature sensing centres in the hypothalamus which regulate food intake. Induced changes in hypothalamic temperature can affect feed intake (Baile and Forbes, 1974).

1.1.1.3 Grazing behaviour

In the grazing situation, food intake may be affected by non-nutritional characteristics of the sward associated primarily with variation in the mass of herbage present and its distribution within the foliage canopy (Hodgson, 1977). In this case, food intake may be restricted by limitations to the adaptability of ingestive behaviour (Hodgson, 1977). Therefore, increases in intake with increasing herbage mass, for example, might be due to either the greater ease of prehension and ingestion of herbage (Arnold and Dudzinski, 1966) or by a greater opportunity for selection (Hamilton et al, 1973).

Herbage intake (I) can be considered as the product of the time spent grazing (GT) and the rate of herbage consumption

per unit of grazing time (RI); the rate of herbage consumption is itself the product of the amount of food ingested per bite (IB) and the rate of biting during grazing (RB) (Allden and Whittaker, 1970) thus :

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

The variation in intake per bite is usually substantially greater than variations in either biting rate or grazing time (Stobbs, 1973b; Hodgson, 1981). Thus under poor pasture conditions, the decrease in intake is often due to the decreased bite size in adult ruminant (Stobbs, 1973a,b). For indoor fed calves, it was demonstrated by Hodgson (1965, 1971ab) that the initial development of the intake of solid feed was related to an increase in the time spent eating, but later increases in the intake of solid feed were achieved by an increase in the rate of DM intake per unit of time spent eating with no further increase in eating time. These observations confirmed the result of Swanson and Harris (1958) who worked with Jersey and Holstein calves.

1.1.2 Factors affecting food intake in the young ruminant.

For the variety of feeds eaten by ruminant calves; physical, metabolic and grazing behaviour controls have been considered in the previous section to be the main mechanisms which control food intake. The mechanisms involved in particular instances in fact may depend on variations in the animal itself, food characteristics and climatic factors.

1.1.2.1 Diet characteristic and food intake

Food intake may be influenced by many of its characteristics. Characteristics of feed to be discussed include form of feed offered, palatability,dry matter content,herbage allowance,and digestibility.

(1) Form of feed

Pelleted feed is dried feed, ground and pelleted. The intake of pelleted feed was found to be greater than the same feed without being pelleted. Owen et al, (1969b) and Kay et al, (1972) demonstrated that lambs and calves were better able to compensate for energy dilution of the diet (by coarse roughages oat husks and chopped straw respectively) when the diet was pelleted than if not pelleted.

Higher food intakes for pelleted feeds could be contributed to by the fact that they are finely ground. Meyer et al, (1959) showed that adding water to ground hay increased consumption and liveweight gain to near that obtained with pelleted hay. It was suggested that the pelleting processes served to put a fine dusty feed in a more palatable form. However, increasing the fineness of grinding of the hay used in the pellets led to a small increase in feed intake (Dobie, 1959).

(2) Palatability

In the young ruminant, shortly after weaning,food intake may be controlled by oropharyngeal factors. Hence "palatability" of feed was of major importance in the development of intake by the calf in the experiment of Preston, (1963). The response to the addition of sweetening agents to the ration appears to be greater in young animals (Preston, 1958; Atai and Harschbarger, 1965) than in adults (Owen et al, 1967 and Brown et al, 1963).

(3) Dry matter content of milk

The consumption of liquid diets is markedly influenced by their dry matter content. With a diet of low dry matter content, a greater volume will usually be consumed than with a diet of high dry matter content. Pettyjohn et al, (1963) showed that when a 10 percent fat milk substitute was reconsitituted at levels of 5 to 25 percent dry matter, the

greatest volume was consumed at the lowest reconstitution rate, but the calves achieved the highest dry matter intake at a reconstitution rate of 15 percent and above. The reconstitution rate of 15 percent was also found to give the greatest efficiency of food conversion. However, reconstitution rates of 20 -25 percents were used in the final stage of fattening of veal calves by Roy,(1980). In fact, the dry matter intake was dependent on the level of milk dry matter intake per day rather than reconstitution rate. There was no difference in dry matter intake when milk substitute powder concentration was 10 or 20 percent in an experiment by Hodgson,(1971e).

(4) Pasture allowance

Herbage allowance, the daily amount of herbage on offer per animal or per unit LW , has been widely recognized as a major factor affecting food intake. Jamieson and Hodgson (1979) showed that herbage intake was reduced by about 19% as daily herbage allowance of 4 - 9 month old calves was reduced from 90 to 30 gm DM/Kg LW/d. In contrast ,milk-fed calves (approximately 58 up to 95 days of age) had similar herbage dry matter intakes at herbage allowance of 20, 40, 60 and 80 gm DM/Kg LW/d respectively but thereafter herbage intake was depressed by 20 gm DM/Kg LW/d (Baker and Barker, 1978).

(5) Digestibility and food intake

The digestibility of the herbage consumed exerts a dominant influence on herbage intake. Hodgson et al, (1977) showed that organic dry matter intake increased at a constant rate as organic matter digestibility (OMD) increased throughout the range between 55 to 81% in the temperate zone and 53 - 63% in the tropical zone. The rate of organic matter intake decrease with decreasing digestibility was much greater in tropical than in the temperate pasture (Hodgson,1977).

1.1.2.2 Effect of animal factors on food intake

(1) Physiological state of animal

The food intake of the grazing ruminant is influenced strongly by the physiological state of the animal. In an experiment where lactating cows, non-lactating cows and weaned calves grazed a sequence of swards varying in maturity and herbage mass, under strip grazing management at a daily herbage allowance of 60 gm DM/Kg LW/d, Hodgson and Jamieson (1981) showed that lactating cows ate 43% and 76% more herbage than non-lactating cows of similar weight during autumn and spring respectively. Herbage OM intakes per kg liveweight by the calves and lactating cows were similar.

(2) Sexes

Comparisons between intact male and female calves (Armstrong, 1966) suggest that sex has no effects initially on the development of the intake of solid feed. A difference in feed intake may however be found when animals are over a certain weight. In lambs, Morgan and Owen (1973) demonstrated that only after lambs had reached 25 kg LW (100 days of age) did a difference in favour of the male lambs become evident.

1.1.2.3 Effect of climate on the food intake

Grazing animals are usually exposed to a variation of climatic factors; air temperature, rain ,wind and day length. These climatic facters have been found to affect food intake of ruminants.

Food intake usually decreases in animals exposed to hot conditions and increase under cold conditions. Kellaway and Colditz (1975) found that the food intake by young cattle increased consistently as temperature decreased from 38C to 20C. An increased food intake under low air temperature is due to the animals being forced to increase their heat production to maintain their body temperature. On the other hand,in high

air temperatures, food intake decreases in order to decrease heat production.

Heavy rain and wind, with cool temperature, usually cause grazing animals to stop grazing and standing in a group. Such behaviour is likely to reduce food intake under conditions which may well cause the need for food to increase.

Daylength also has an influence on food intake by modifying grazing pattern. During day time, grazing ruminants normally have two main grazing periods,after dawn and before twilight. However during shorter daytimes or in hot weather, especially if there is moonlight,from 14-35% of the grazing time occurs during the night in cattle (Ruckebusch and Bueno,1978) and up to 40% with sheep in a Mediteranean climate (Theriez et al, 1979). Rumination also occurs during the night (50-70%) if the daytime is short and eating time is long.

The grazing pattern of grazing cows could also be modified by the weather. When the air temperature or relative humidity is high, animals may start to graze early in the morning, cease in the middle of the day and graze again at the end of the afternoon and during part of the night (Cowan,1975 ; Hancock,1953).

1.2 EFFECT OF SUPPLEMENTS ON PERFORMANCE OF YOUNG CALVES

Young ruminants that are weaned on to pasture at an early age usually suffer from weaning stress due to a low consumption of solid feed. This effect may be due to various factors (eg. diet characteristic, animal factors, see section 1.1.2) which in fact are controlled by physical and chemical mechanisms as well as eating behaviour.

Supplements are referred to as those feeds offered to animals in addition to the basal food,to promote animal production (eg. growth). The supplements used are normally characterized by some or all of the following : a high nutritive value, high bulk density, ease of eating (higher rate

of eating), high utilisation or some of these characteristics. Therefore, the feed consumption of calves receiving a certain amount of supplement (eg concentrates) should not be limited primarily by physical mechanisms or eating behaviour,but be being limited by their requirements.

1.2.1 Concentrate supplements

Gleeson (1971) found that calves weaned on to an all-grass diet at an early age had a lower rate of liveweight gain than calves fed skim milk or concentrates in addition to grass.

Concentrates are better than pasture in promoting liveweight gain in early-weaned calves. This was primarily due to higher voluntary DM intakes. In an experiment comparing the use of pasture with concentrate as an early weaning food for calves,Byford (1973) found that despite pasture and concentrate having similar DE coefficients, calves receiving concentrate had a significantly higher DE intake than calves receiving pasture. However, as the calves grew, the effect of feeding supplement to calves on growth rate appeared to decline. In one grazing study with calves (initially 8 weeks of age) concentrate supplement did not increase growth rate (Castle and Walker, 1959).

The effect of concentrate supplement on dry matter intake, digestibility and calf performance may be influenced by the chemical and physical characteristics of the concentrate supplement on offer. Those characteristics include concentration and balance of energy and protein,and level of roughage. Interactions between these characteristics and level of feeding are also important.

(1) Content and balance of energy and protein

The young ruminant, receiving pelleted diets containing different concentrations of digestible energy, attempts to keep its digestible energy intake constant (Montgomery and Baumgardt, 1965). This being so, dry matter intake should decrease as the energy content of the diet increases so that the energy intake of the animal remains constant at the level limited by animal requirement (see section 1.1.1.2 metabolic control). In contrast, Friesian calves given diets having either 12.97, 11.72 or 10.04 MJME per Kg dry matter, digestible intake and liveweight gain tended to decrease as energy concentration of the diet increased (Kay et al, 1970). It was suggested that this was due to the inclusion of fat in the high energy diet (Miller et al, 1959) which had a harmful effect on intake.

A high crude protein content in an early-weaner diet increased DM intake, and liveweight gain but did not effect dry matter or crude protein digestibility (Trotta et al,1984). The experiment compared low (13%) and high (18%) CP in the diet for calves weaned at 5 weeks of age and it was shown during weeks 6 to 12, calves on the high protein diet ate more DM (2.14 and 1.71 Kg DM/d) and gained more liveweight per day (0.83 and 0.60 Kg/calf daily) than those on the low protein diet. However, apparent digestibility of dry matter (67.3 and 66.3) or crude protein (62.7 and 61.6) were not significantly different between the high and low protein levels as fed to 12 to 13 week old calves. Similarly, Preston et al (1965) suggested that for calves weaned at approximately 4 weeks of age, and receiving an all-concentrate diet, a level of 17-19% crude protein in the dry matter, supplying 270-340 g. digestible crude protein per day, was required. In contrast, Jacobson (1969) demonstrated that 12% crude protein in a calf starter (or 170 g of digestible protein) is adequate for 0.72 kg/d growth rate. Such disagreements are probably because protein composition (amino acid balance) and solubility as well as protein concentration affect intake and growth rates in calves. Protein reaching the abomasum and small intestine for digestion

is a result of rumen microbial synthesis and dietary protein escaping microbial degradation, thus net amino acids absorbed are derived from dietary and microbial protein. In early-weaned calves and lambs, microbial protein synthesis may not be adequate for maximum growth and animals should respond to increased dietary escape protein provided the amino acid composition of the protein is of high quality (Ørskov, 1977). The mean rate of liveweight gain on the diets with 19.4% crude protein was 898 g/day and 454 g/day for fish meal and ground nut as the protein source respectively (Preston et al, 1965). Fish meal is a significantly better source of protein than ground nut meal. Whitelaw et al (1961b) found that the higher nitrogen utilisation of fish meal compared with ground nut meal was almost entirely due to differential urinary nitrogen losses partly associated with the more favourable amino acid make up of fish meal protein (Preston et al, 1964). It was shown that feed intake may be reduced in response to the absorption of an imbalanced mixture of amino acids (Egan and Rogers,1978). Trotta et al (1984) found that solubility of dietary protein affected daily gain of early-weaned calves fed only on diet containing 13-15% CP but not at 17% CP. Dry matter intakes and growth rates were increased in 4-16 month old heifers receiving diets containing the more insoluble (36 or 70%) CP sources (Amos, 1985).

The balance of energy and protein in concentrate diets is probably important in determining feed efficiency. Preston et al (1965) found that nitrogen retention as a percentage of dietary intake appeared to be less on the diet with 21.75% crude protein in dry matter than 14.8-19.4%. It was suggested that the limiting factor to further nitrogen retention was energy not protein.

(3) Level of roughage in diet

The inclusion of a certain amount of roughage in concentrate diets promotes increased food intakes and liveweight gains of calves (Kang and Leibholz, 1973; Kellaway et al, 1973a; William et al, 1984) presumably due to an

increased rumen-buffering capacity as a consequence of greater saliva production (Kellaway et al, 1973a). Rumen pH of calves offered roughage is increased thus preventing the hyperacidity that is inhibitory to voluntary food intake (Kellaway et al, 1973b). However, voluntary consumption of long roughage restricts roughage intake to between 40 to 90 g/Kg total intake (Roy, 1980; Thomas and Hinks, 1982). Therefore, a complete diet (incorporating the roughage fraction) is required if higher levels of roughage consumption are desired. Likewise, to maintain similar rumen-buffering qualities associated with long roughage, it is essential that a greater quantity of chopped material is used (Thomas and Hinks, 1982).

The dilution of a concentrate pellet (used for weaner calves) with ammonia treated barley straw (15-25% on dry matter basis) had no significant effect on liveweight gain, DM intake, and rumen volume of calves from 6-13 weeks of age (William et al , 1984). Similarly,Thomas and Hinks (1983) suggested that post-weaning food intakes of calves should be maximised with 240 g chopped straw per kg of diet was suggested by. However the inclusion of increasing quantities of roughage in the diet increased the level of gut residues, with consequent decreases in empty body-weight. There the post-weaning empty body-weight gains were maximized at the inclusion rate of 130 g straw per kg of diet (Thomas and Hinks, 1983).

Roughage inclusion in the diet also guards against rumen disorders such as bloat (Preston et al, 1961), where its functions appear to be two fold : it promotes greater rumen motility as a result of its physical properties (Clarke and Reid, 1974) and it is also associated with a physiological effect of preventing hyperacidity, which can suppress rumen contractions (Ash and Kay, 1959).

(4) Level of concentrate feeding

When ruminants are fed roughage ad libitum plus a limited supply of concentrate, the higher the DM allowance of concentrate the higher will be the substitution rate (decrease

of DM intake of roughage per unit increase DM intake of concentrate). Total intake is also generally increased when the DM allowance of the concentrate in the ration increases but, for a very high supply of concentrate, it may decrease (Baumgardt, 1970). The drop in DM intake when the proportion of concentrate in the ration exceeds a certain limit cannot be due to a slowing down of digestion in the rumen or to a limitation of the chewing time, but to metobolic factors (Baile and Mayer, 1970).

As the level of meal allowance increases, the growth rate of early weaned calves normally increases . In an experiment where meal allowance was offered from zero to ad libitum, Donnelly (1977) found that liveweight gain increased by 19 g for every 100 g increase in meal eaten. The liveweight gain ranged from 700 g/d for the ad libitum group down to 460 g/d for the group on pasture only. The greatest response to concentrates occurs with roughages of low digestibility (Leaver, 1973). The intake of roughage was depressed by increasing the level of concentrate supplementation with the greatest depressions occurring with roughages of high digestibility (Leaver, 1973).

The short term benefits from feeding meal can be subsequently lost where high-quality pasture is readily available. Thus Donnelly (1977) found that during a a 4-week follow-up period, when all calves grazed pasture as one mob without meal supplementation, growth rates were negatively related to previous meal allowance and negated the liveweight advantage resulting from meal supplementation. It was suggested that animals previously fed the lower meal allowances exhibited compensatory growth while others at the higher meal allowances showed negative compensation. Growth rates in the remainder of the follow-up period were unrelated to previous treatment (Donnelly , 1977).

1.2.2 Milk supplement

Milk is characterized by high utilisation, digestibility, energy content and ease of eating. Milk is the main food for young calves after birth since milk can supply nutrients to meet the high demand during early life. Although early weaning systems are being introduced to reduce feed and labour costs for calf production, some milk is obviously still needed for calves grazing pasture. Those factors concerning milk feeding which will be discussed include: age and rate of weaning, frequency of feeding, method of feeding, form of milk fed and level of feeding.

(1) Age and rate of weaning

Calves weaned off milk at an older age (4 weeks of age) had a higher subsequent rate of solid food intake and were less severely affected by weaning than younger calves (3 weeks of age) (Hodgson,1965),and the rate of weaning (7 days and 14 days) had little effect on either the development of solid food intake or on the severity of the weaning check. The severity of the post-weaning check was inversely related to age at weaning, but was not affected by weaning weight (Hodgson,1965). In contrast, Gleeson (1971) found that age of weaning (6, 9, 12 or 15 weeks of age) had no effect on subsequent daily dry matter intake from grass. Immediately after the calves were weaned on to an all-grass diet, their intake of grass dry matter rapidly increased.

(2) Frequency of milk feeding

The present moves towards greater intensification and larger units means that methods of feeding calves are being modified to reduce time and labour.

Feeding whole milk either once or twice a day had no significant effects on performance (Owen and Harris, 1965) and there was no effect on concentrate intake during pre- and post-weaning period (Khouri, 1969). Similarly, Randall and

Swannack (1975) found that performances of replacement calves were not significantly different between once and twice-a-day feeding with milk substitute fed either warm or cold. However for beef calves, once-a-day feeding with a cold milk substitute resulted in lower liveweight gain than those fed twice, and is not advisable for calves reared solely on liquid diets at high levels. Although once a day feeding could save time and labour in feeding calves, there are certain standards that must be maintained (Randall and Swannack, 1975). First of all, milk substitute must be good and mixed well in cold water. Secondly, clean water must be available to all calves as their liquid intake is cut by half in most cases.

(3) Method of feeding milk

Milk can be fed to young calves either by artificial teat or by bucket. Feeding milk by artificial teat has sometimes been found to be superior to feeding by bucket. In a study with Jersey calves fed whole milk to 28 days, Stewart (1976) found that artificial teat feeding reduced mortality, feed refusal and increased liveweight gain while bucket fed calves suffered from considerable diarrhoea and a high mortality (29%). Feeding milk with artificial teat at a fast rate of drinking significantly reduced the incidence of diarrhoea. The inferior performance of calves drinking milk from buckets was due to the inefficient functioning of the reticular groove. When calves suck milk voluntarily, lips of the groove normally contract and rotate to form a tube permitting direct passage of most of the ingested fluids through the cardia to the reticulo-omasal orifice, but when they drink from a bucket, constancy of groove closure and predictability of fluid destinations diminish (Wise and Anderson, 1974). However, in all calves during the first six weeks, liquid intake closed the oesophageal groove (Hegland et al, 1957), and artificial teat caused closure of the groove for at least 13 weeks, whereas bucket-feeding was less effective after six weeks.

(4) Form of milk fed

Milk is normally fed to calves in a liquid form. Feeding milk as powder could save time and labour costs in rearing calves. The comparison between feeding milk,dry and liquid form,has not been done in young calves during post-weaning period. However, in older calves (14-30 weeks of age), supplement milk to grazing calves as liquid or dry form had no effect on growth rate,herbage intake or total DM intake (Keane and Harte, 1982). Similary Bush and Nicholson, (1986) fed liquid fish meal and dry fish meal for an additional 140 days to calves weaned at 35 days old, there was no difference on growth rate between two groups. It was suggested that any increased rumen by-pass through the oesophageal groove reflex did not result in improved animal gain.

(5) Level of milk feeding

An inverse relationship between the level of milk fed and the intake of solid feeds (pasture and concentrates) has been demonstrated in grazing calves by Baker et al, 1976 and in indoor calves by Wang et al,1985; Harte et al,1984; Huber et al,1984;and Hodgson,1971e.

There was a close positive relationship between milk intake and liveweight gain before weaning (at 5-6 weeks) but weight gain after weaning was not affected by the level of milk intake before weaning (Hodgson, 1971e). Similarly, in an experiment where milk was offered to calves indoors at high (6l) and low (4.5l) daily levelsfrom 3-7.5 weeks of age, Wang et al (1985) found that calves on the high milk level grew faster than on the low milk level in the pre-weaning period but no differences were observed from then on.

Diarrhoea is often associated with higher intakes of milk (Hodgson, 1971e). In contrast Huber et al (1984) found that "scour score" were not significantly different between calves fed at high and low milk level. It was suggested that sanitary and management conditions probably play a more important role

than amount of milk in affecting the incidence of diarrhoea in young calves (Huber et al, 1984).

The total DE intake during the pre-weaning period (4.5 weeks) plus post-weaning period (3 weeks) did not differ between high and low milk feeding in the experiment of Wang et al, 1985. It was concluded that increasing the level of milk fed in the pre-weaning period decreased herbage intake both during and for a period after weaning. That is any superiority in growth rate achieved at weaning is subsequently lost.

1.3 THE ENERGY AND PROTEIN REQUIREMENTS OF YOUNG CALVES

1.3.1 Energy requirement

The energy requirement of calves,as for other animals, may be subdivided into that required for maintenance and that required for growth. Energy required for maintenance is the energy intake that results in zero growth rate. Energy above that required for maintenance is stored in the body mainly as fat and protein, and results in growth of the calf.

1.3.1.1 Energy requirement for maintenance

Energy for maintenance is used by animals in the following ways:

(1) the basal metabolism, which is the heat produced as the result of oxidation of body tissue to provide energy for respiration, circulation, muscle activity and other vital processes, 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 tissue 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, the sum of the fasting heat production and fasting urinary loss of energy, is used as a base to estimate the maintenance requirement of animal. It can be obtained with the calf at rest and when the post absortive state after feeding has been reached. The calf must also be kept in a thermoneutral environment in the calorimeter.

Fasting metabolism of the calf is not a constant value but varies with age. For the Holstein the fasting metabolism was shown to decline from about 540 $kJ/kg^{0.73}$ at 3d of age to 347 $kJ/kg^{0.73}$ at 28d. (Roy, 1980). There was no significant difference in fasting heat production between the breeds (Friesian and Jersey calves) but previous level of feeding had significant effects (Holmes and Davey, 1976).

Beef calves have a lower basal metabolism than dairy calves. Roy (1980) showed that basal metabolism for beef calves was 10 percent lower at 2 months of age and 19 percent lower at 12 months of age. Within both the dairy and beef breeds the greater the breed mature size the lower the basal metabolism per unit metabolic weight.

For calves on pasture, more energy is lost for walking around to graze pasture than occurs in indoor fed calves. Basal metabolism for calves reared indoors and in open sheds were 423 and 460 $kJ/kg^{0.73}$ respectively (Johnson and Elliot,1972a,b).

Fasting metabolism can be estimated from the following equation (ARC, 1980). $F = 0.53W^{0.67}$ where F is fasting metabolism (MJ/d) and W is fasted weight (kg).

Energy required for maintenance is also dependent on the efficiency of utilisation of metabolisable energy for maintenance (k_m) which is defined as the increase in energy

retention per unit increase in metabolisable energy supplied. Energy required for maintenance of the animal is the fasting metabolism divided by the k_m value. The k_m value is strongly influenced by metabolizability qm (metabolisable energy of a diet divided by their gross energy) according to the equation $k_m = 0.546 + 0.30$ qm (ARC,1980). Therefore the higher the metabolisability of the diet the higher the efficiency of the utilisation of metabolisable energy.

The inefficiency of 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). Therefore, the nature of the diet influences this part of energy loss.

(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).

Some estimate of ME required are shown in Table 1.1. Those estimated values for maintenance from New Zealand (Holmes and McLean,1975;Holmes and Davey,1976; Hughes et al,1977;Holmes et al,1978) are a bit lower than those from other countries. (Roy 1984).

Table 1.1 Some estimates of ME_m of calves given liquid diet of milk or milk substitute or dry feed

Sources		MJ ME/$kg^{0.75}$	Breed and diet
Blaxter and Wood	(1952)	0.455	Ayrshire, whole milk
Van Es et al	(1969)	0.436	Ayrshire, milk replacer
Holmes and McLean	(1975)	0.409	Jersey, whole milk
Holmes and Davey	(1976)	0.393	Jersey and Friesian, whole milk
Hughes et al	(1977)	0.41	Friesian, whole milk and concentrate
Holmes et al	(1978)	0.43	Friesian, hay and pellets

1.3.1.2. Energy requirement for growth

In young calves, ME ingested above that required for maintenance is used for growth in the form of fat and protein tissue. Energy required for growth depends on the energy content per unit of liveweight gain and the efficiency with which energy ingested is deposited as net energy of gain.

(1) The energy content of liveweight gain

The growth of animals, in fact, is the deposition of protein and fat plus water in the liveweight gain. The energy content of protein and fat are 24.37 and 39.33 MJNE/kg respectively. Therefore, the ratio of protein to fat determines the energy content per unit weight gain. The energy content in weight gain varies with some factors: growth rate, age, sex, mature body size.

The faster the animal grows, the higher the fat content

in the gain, so the energy content is also higher (Lofgreen and Garrett, 1968). The energy content of empty body weight gain can be estimated by the following equation (A.R.C., 1980)

$$E = (4.1+0.0332W-0.000009W^2)/(1-0.1475WG)$$

where E is the heat of combustion of liveweight gain (MJ/kg), WG is rate of gain (kg/d). (This value is estimate for castrates of medium breeds).

As calves grow, fat content in liveweight gain also increases. In the young animal, fat retention may account for as little as 50% of the retained energy while this value varies from 85% to 95% in adult animals (ARC, 1980). Energy content per unit live weight gain is, therefore, lower in young than older animals.

Energy content also differs between sexes. Male animals have higher protein and lower fat content in the weight gain than female animals (Garrett, 1970). Therefore energy content per unit liveweight gain in the male is higher than for female animals.

Calves differ between breeds which have different mature body sizes. It was found that animals with different mature body size have different energy content per unit liveweight gain (ARC, 1980). Animals with a larger mature body size have lower energy content per unit liveweight gain than those with a small mature body size.

Furthermore, liveweight gain also varies with the amount of gut fill. The percentage of it in liveweight gain varies with the feed properties and calf age. The higher the digestibility of the feed the lower the gut fill.

(2) Efficiency of utilisation of metabolisable energy for growth (K_g)

The efficiency with which energy is deposited as fat is higher than for protein. In infant ruminants or simple-stomached species, the efficiency with which fat and protein is deposited is about 0.70 and 0.45 respectively (Breirem and Homb, 1972; Kielanowski, 1976 cited by ARC, 1980). In New Zealand, for calves between 3 and 37d of age, the efficiency of utilisation of metabolisable energy for fat and protein was 0.79 and 0.54 respectively (Holmes and Davey, 1976). The overall efficiency of utilisation of metabolisable energy for growth is about 0.70 as in Table 1.2. The quality of feed also has a large influence on k_g value. The value for ruminating calves is lower than for calves receiving milk or milk substitutes (see Table 1.2). However, it was found that there was no major difference between a diet of milk alone or milk plus solid food on net efficiency of utilisation of ME by calves (Holmes and Davey, 1976).

Table 1.2 Efficiency of utilisation of metabolisable energy for growth in calves given milk or milk substitutes or dry feed

Authority		Efficiency	Breed, diet
Gonzalez - Jimenez and Blaxter	(1962)	0.77 - 0.81	Ayrshire, whole milk
Van Es et al	(1969)	0.69	Ayrshire, milk replacer
Webster et al	(1976)	0.72	Friesian, milk replacer
Holmes and Davey	(1976)	0.67	Jersey and Friesian, whole milk
Holmes et al	(1978)	0.51	Friesian, hay and pellets
Hughes et al	(1977)	0.63	Friesian, whole milk and concentrate

The requirement of ME for liveweight gain was 14.89 MJ/kg in Friesian calves fed milk and concentrate (Hughes et al, 1977). However, the higher level of feeding resulted in a slightly higher ME requirement per kg of liveweight gain (16.53 and 12.85) compared to a lower feeding level. In young calves fed fresh milk, ME required for growth were 13.6 and 11.3 MJME/kg of liveweight gain for higher and lower rates of gain respectively (Holmes and Davey, 1976)

1.3.2 Protein requirement

Similar to energy requirement, calves require protein for maintenance and growth. The maintenance requirement is assumed to be equal to the endogenous urinary nitrogen excretion (UN) and metabolic faecal nitrogen (FN). The protein reguirement for growth is the amount of N expected to be retained in weight gain (RN).

1.3.2.1 Total tissue nitrogen requirement of calves

(1) Endogenous urinary nitrogen (UN)

If a calf is given a nitrogen-free diet, there is still a loss of nitrogen in the urine and faeces. The loss of nitrogen in urine is a result of metabolic processes in the tissues and is called the endogenous urinary nitrogen. With pre-ruminant calves, the value is between 63 and 82 mgN per kg bodyweight per day (Blaxter and Wood, 1952) or 184-193 $mgN/kg^{0.75}$ per day (Roy et al, 1970). This loss of nitrogen decreases with age. With ruminant calves values decreased from 58 to 25 mgN per kg liveweight per day as calves aged from 12 weeks old to a liveweight of 283 kg (Roy, 1980).

(2) Metabolic faecal nitrogen (FN)

This is the loss of nitrogen in the faeces arising from the digestive juices, bacterial residue and epithelial cells that become eroded during the passage of food through the digestive tract. It depends on the dry matter intake and the

amount of fibre in the ration. The loss increases as the fibre content of the diet increases. These values are 1.9 and 3.3 g N per kg DM intake for calves given whole milk, and a diet containing 5 percent crude fibre respectively (Roy et al, 1964; Stobo et al 1967).

(3) Nitrogen content of weight gain (RN)

The amount of nitrogen stored per kg weight gain was approximately 26 to 34gN for calves weight 50-70kg LW and it declines at liveweight above 200kg (Roy, 1980). The amount of nitrogen stored appeared to be higher for slow-growing calves and in calves receiving a diet containing a high concentration of protein.

1.3.2.2 Biological value of protein (BV)

BV of a protein is defined as the proportion of truly digested protein that is retained as protein in the body. In the pre-ruminant calf, the BV reaches its maximum when the supply of amino acids from the protein is in exactly the correct proportions for the requirement of the calf or when the diet being given to the calf contains an excess of energy (Roy, 1980). It was found, in this condition, that BV of milk protein is 80% or even as high as 90% (Brisson et al, 1957; Blaxter and Wood, 1952).

1.3.2.3 Estimates of protein requirement

The protein requirements of the ruminant animal as apparent digested protein is calculated by the following equation.

$$ADP = 6.25 \{ (RN + UN + FN*D) - FN*D \} / BV$$

where ADP is apparent digested protein (g/d), RN is N retention (g/d), UN is endogenous urinary N (g/d) ,FN is metabolic faecal N (g/kg DM intake),D is DM intake (kg) and BV is biological value (as a coefficient) (Roy,1980). For exsample ,the apparent digested protein requirement of ruminant calves of 60-80kg for maintenance and 0.5 kg liveweight gain were 35-40g

and 155-160g respectively (Roy,1980). For calculation of the protein requirement the following factors have been used: UN = 184.4 mg/$kg^{0.75}$;RN = 30gN/kg liveweight gain ;BV = 0.80 ; FN = 3.3g/kg DM intake;D = 1.6-1.8 kg DM intake/d.

For ruminant calves, a new system (see ARC 1980) has been used to assess total protein requirement (TP). Since total protein required by animal tissue is met by microbial protein from rumen and dietary protein which has escaped fermentation in the rumen. To achieve maximum microbial protein synthesis in the rumen, it is necessary to have an adequate amount of rumen degradable protein(RDP) in the diets for use by the micro-organisms. This value can be calculate by the following equation (ARC,1980).

$$RDP = 7.8\ ME$$

where RDP is the minimum rumen degradable protein requirement (g/d),ME is metabolisable energy intake (MJ/d) and the maximum tissue protein supplied by microbial protein (TMP, g/d) is:

$$TMP = 3.3ME$$

If TMP is insufficient to cover the needs of the calf for a particular level of production, then the deficit must be supplied by protein that has escaped degradation in the rumen which is calculated from the following equation:

$$UDP = 1.91\ TP - 6.25\ ME$$

Where UDP is undegraded protein (g/d),TP is total protein requirement (g/d) and ME is metabolisable energy intake (MJ/d). Therefore, total protein is the sum of RDP and UDP. Some estimates of RDP and UDP for calf of 100kg LW are shown in Table 1.3.

Table 1.3 RDP and UDP requirement (g/d) of cattle for maintenance and growth (ARC,1980)

			liveweight gain (kg/d)			
	LW		0	0.25	0.5	0.75
Male calf	100	RDP	145	160	185	205
		UDP	-	35	105	170
Female calf	100	RDP	125	150	175	205
		UDP	-	35	100	150

1.4 ESTIMATION OF FEED INTAKE BY MARKERS FOR GRAZING RUMINANTS

1.4.1 The indirect measurement of food intake

The use of markers to estimate feed intake of grazing animals have been intensively reveiwed by Greenhalgh (1982) ;Le Du and Penning (1982) and Kotb and Luckey (1972). Feed intake can be indirectly estimated by the following equation:

$$I = F/(1-D)$$

Where I is feed DM intake (g/d), F is faecal DM output (g/d) and D is feed digestibility as a decimal. This method was first described by Garrigns (1934). It was realized that both faecal output and feed digestibility might be estimated by the use of marker technique.

The criteria for the ideal marker were listed by Raymond and Minson (1955) as follow:

(1) It should be neither absorbed nor normally retained in the digestive tract.

(2) it should be non-toxic;

(3) it should be readily analysed by physical or chemical methods;

(4) it should be present only in small amounts in the original diet.

Two main classes of markers are used in indirect estimation of food intake and those are internal markers and external markers. Internal markers occur naturally in feedstuffs , such as lignin, chromogen, nitrogen or silica whereas external markers originate outside the diet, such as chromic oxide and polyethylene glycol.External markers such as chromium oxide are most widely used to estimate faecal output of grazed animals. The external marker is given to animals in a known quantity either directly (eg as a capsule) or by addition to the feed. If an animal is given a constant quantity daily (g/d), it will on average excrete the same quantity daily. Faecal DM output can be calculated as:

$$F = \frac{G}{E}$$

where F is faecal DM output (g/d), G is the amount of marker excreted (g/d) and E is the concentration of marker in faeces DM (g/g).

Internal markers are used to estimate the digestibility of forage grazed by animal. As a feed passes through an animal, its concentration is progressively increased by removal of other constituents through digestion and absorption. The digestibility coefficient of feed dry matter can be calculated by the following equation.

Herbage intake (I) x ih = Faecal output (F) x if.

where ih and if are percentages of internal marker in feed and faeces respectively.

Therefore the digestibility coefficient = $1 - \frac{ih}{if}$

This technique is called the ratio technique. The digestibility of herbage can also be calculated by the faecal index technique and the in vitro digestibility procedure (see Le Du and Penning, 1982; Kotb and Luckey, 1972).

1.4.2 The use of chromium oxide and polyethylene glycol as markers

(1) Chromium oxide (chromium sesquioxide, (Cr_2O_3)

Chromium oxide is one of several chromium compounds with characteristics of inert indicators. Others are chromium chloride ($^{51}CrCl_3$), sodium chromate ($Na_2{}^{51}CrO_4$) and ^{51}Cr-labelled crythrocytes. Only chromium oxide has been used widely in both radioactive and non-radioactive forms in studies of food utilisation (Kotb and Luckey,1972).

Chromium oxide is light to dark green in colour and practically insoluble in water, alcohol or acetone but slightly soluble in acids and alkalis (Merck Index, 1968 cited by Kotb and Luckey,1972). Numerous types of administered Cr_2O_3 have been tried but only four are in general use: gelatine capsule 1g or 10g Cr_2O_3 in oil base, paper impregnated with Cr_2O_3,incorporate the marker into feed (Le Du and Penning, 1982) and in controlled release device (CRD).

The use of chromic oxide as a faecal marker was first proposed by Edin (1918 cited by Le De and Penning, 1982). In dairy cows, mean recovery rate of chromic oxide is 99.9% (96.7 to 102.1%) (Kane, Jacobson and Moore 1950b). However, concentration of Cr_2O_3 in the faeces may show considerable diurnal fluctuations when it is administered in discrete doses. Hardison and Reid (1953) found a variation in recovery rate from 0.8 at 12.00 hours to 1.3 at 18.00 hours for grazing steers which were dosed once daily with 10g Cr_2O_3. More

frequent administration of the marker appears to eliminate diurnal variation of marker concentration in faeces. Pigden and Brisson,(1956); Brisson, et al (1957) claimed that no variation in Cr_2O_3 concentration occurred in the faeces of grazing animals (sheep and cattle) when the marker was administered in gelatine capsules every four hours. A preliminary dosing period is necessary to ensure stable conditions are reached prior to sampling the faeces to determine marker concentration. The time required for Cr_2O_3 to equilibrate throughout the gut is influenced by the level of intake and by the characteristics of the feed, as the rate of excretion of the marker is related to the rate of passage through the digestive tract. It was suggested that the preliminary dosing period should be at least 10 days (Brisson et al, 1957). However,Le Du and Penning, (1982) concluded from 55 experiments that using Cr_2O_3 as a marker will generally estimate faecal output to within ±6% and the following procedures are recommended:

1. preliminary dosing period of 7 days;

2. with animals being dosed twice daily at approximately 8 and 16 hour intervals and faeces samples taken at the same time over at least a 5 day period;

3. use of Cr_2O_3 in slow release form, reduces diurnal variation in marker excretion.

Several methods for digesting and analysing Cr_2O_3 have been described. The digestion procedure was outlined by Stevenson and De Langen (1960); and Christian and Coup (1954). Methods for analysis of chromium by titrimetric method were given by Fisher et al, (1972); by atomic absorption spectrometry method both an air-acelylene flame and a nitrous oxide - acetylene flame (Goguel, 1970); by inductive coupled plasma emission spectrometry method (i.c.p.e.s., Fisher and Lee, 1982). Lee et al, (1986) found that titrimetric method showed the least imprecision (0.67%RSD) compared with 2.1%RSD

for the i.c.p.e.s. method and 4.7%RSD and 5%RSD for the atomic absorption method of nitrous oxide-acetylene and air-acetylene flames respectively. The most suitable range of chromium concentrations for analysis by atomic absorption was found to be 0.8-70pp.m in solution. However, the lower limit could be decreased to 0.15p.p.m. by use of the scale expansion device (David, 1961).

(2) Polyethylene glycol (PEG)

PEG compounds are manufactured through the reaction of ethylene oxide with water and ethylene glycol or diethylene glycol. Polyethylene glycols of 200-600 are fluids, compounds of 1000 - 10,000 are solid of increasing firmness (Kotb and Luckey, 1972). The number gives the approximate average molecular weight.

In studies of ruminant digestion, PEG (molecular weight 3000-3700) has been used as a marker, was found not to be absorbed nor destroyed to any considerable extent in the digestive tract and more than 90% was recovered in the faeces (Sperber et al, 1953). Since PEG is a water-soluble marker, it associates with the water of the digesta. It was found that the maximum variations in PEG concentration in the dry matter of seperate defaecations were ±40 to 60% from the 24 hour weighted mean concentrations compared to 10% on the similar basis for Cr_2O_3 (Corbett et al, 1958).

The standard concentration range from 0.5-5.0mg PEG/100ml can be accurately read by nephelometer with the readings reaching a maximum after 1-6 min (see Corbett et al, 1958).

The quantitative measurement of PEG by a gravimetric procedure, was devised by Shaffer and Critchfield (1947). However, a faster and more accurate method is the turbidimetric method introduced by Hyden (1955a) which has been modified by several workers (Corbett et al, 1958; Smith, 1959; Ulyatt, 1964a.)

CHAPTER 2

MATERIALS AND METHODS

2.1 EXPERIMENT DESIGN

The experiment was of a randomised block design with four blocks each of eight calves (four males and four female calves).The calves,within blocks and sexes,were randomly allocated to each of the four treatments. The experiment was to compare alternative supplements for 5-10 weeks old calves grazing pasture. The four treatments were as follow:

treatment i	Supplement of concentrate meal containing soya bean (S).
treatment ii	Supplement of concentrate meal containing milk powder (P).
treatment iii	Supplement of liquid milk (and small amount of concentrate: carbohydrate mix (L).
treatment iv	No supplement (G).

The experiment was divided into three main periods, I,II and III. The experimental description is summarised in the Table 2.1.

Table 2.1 The experimental description

Period	class	age (weeks)	treat ment	food	amount
I	preliminary	birth to		milk	ad libitum an average of 7 l/calf daily
	period	5-6	-	concentrate[1/]	ad libitum
				pasture	ad libitum
II	comparison period	5-6 to 10-11	1	soya bean mix	1kg/calf daily
				pasture	ad libitum
			2	milk powder mix	0.75kg/calf daily
				pasture	ad libitum
			3	carbohydrate mix	0.23 kg/calf daily
				milk	4 l/calfdaily
				pasture	ad libitum
			4	pasture	ad libitum
III	post comparison period	10-11 to 33	all	calves grazing pasture together (within sex groups) plus concentrate[1/] 1kg/calf daily	

[1/] Commercial concentrate (Snow ball No 103,17.5 % crude protein,CP)

2.1.1 Period I (Preliminary period)

Sixteen Friesian bull calves and sixteen heifer calves born in March and April 1986 (Autumn calves), from the Massey University No 1 dairy herd,were used. Following the rearing system used by No 1 dairy farm, calves were left on their dam (in paddock) for 24 hours and then fed milk ad libitum, while in a pen indoors, for a week. The calves were then put out to grazing in groups of 20 calves and they were changed to a new paddock every 3-4 days. In addition to milk ad libitum they

were offered a concentrate supplement. At 5-6 weeks of age, four males and four female calves were selected to form each of the four blocks. Within blocks, calves were similar in terms of age and body weight. All calves used in this experiment were healthy any "defect" calves were not selected. Each calf was drenched for stomach worms with 14 ml of " Systemex " before being put onto the treatment.

2.1.2 Period II (Comparison period)

During the main experimental period, calves were offered one of four rations for 5 weeks commencing at 5-6 weeks of age. The objective of this period was to compare the responses in performance (liveweight gain and health) and to measure herbage intake as a factor which may influence performance. The calves were treated uniformly and grazed in the same paddock but recieved the supplements in separate groups.

Any calves that showed signs of scouring during period I and II were drenched with "Scour Ban" (Product of Vetc Products,Auckland).

2.1.3 Period III (Post-comparison period)

Calves in this period were grazed in two mobs,males in one and females in the other,but were otherwise treated similarly. The objective of this period was to compare the carry over effect of experimental treatments on liveweight gain up to 7-8 months of age.

During period III, all calves were drenched with "Systemex" at the time they were brought in for weighing (every 4-6 weeks).

2.2 EXPERIMENTAL FOODS

2.2.1 Milk

Milk used in the experiment was reconstituted from a fat-fortified milk powder(Ancalf). Milk substitute powder was mixed with warm water (at about 38°C) before feeding (0.52 kg of powder in 4 litres of warm water) and was fed daily to each calf in treatment L.

2.2.2 Concentrate Supplements

There were three concentrate supplements used in the experiment (period II). The soya bean mix and milk powder mix were designed to provide 11.28 MJME and 175 gms CP for each calf daily (calculation based on nutritive values of feed stuffs proposed by Holmes and Wilson, 1984). The carbohydrate mix together with liquid milk was also designed to provide the same energy and protein intake. The ingredients used in the three "dry" supplements were as shown in Table 2.2.

Table 2.2 Feed ingredients used in supplements

Ingredients	concentrate supplements		
	Soya bean mix(%)	Milk powder mix(%)	CHO[1/] mix(%)
Soya bean meal (50 %CP)	25.0	-	-
Maize meal (8 %CP)	20.0	8.4	27.0
Barley meal (11 %CP)	50.0	21.1	68.0
Milk powder (30 %CP)	-	69.0	-
Molasses	5.0	1.5	5.0
	100.0	100.0	100.0

[1/] CHO mix is carbohydrate mix.

The soya bean and carbohydrate concentrate supplements were pelleted and the milk powder mix was fed in powder form since it was too fine to be pelleted.

2.2.3 Pasture

The pastures used were predominantly ryegrass and white clover. Paddocks of 2 ha were used in rotation. Four groups of calves were kept in the same paddock divided into four equal areas by two electric wires. The herbage allowance was approximately 60 g dry matter(DM)/kg liveweight(LW) daily so that allowance would not limit herbage intake (Baker and Barker,1978).

2.2.4 Water

Water was provided at all times in 200 litre plastic drums in each subpaddock. Calves were able to suck water from rubber teats attached to the drums. Water was changed every 1-2 days in order to provide fresh water at all times. During Period II water intakes were recorded every day for each treatment group

2.3 EXPERIMENTAL PROCEDURES

2.3.1 Calf growth performance

During period I and II liveweight (LW) was measured weekly on Wednesday at 0800 h on electronic scales accurate to ±0.50 kg but during period III liveweight was measured every 4-6 weeks. All the measurements were done before feeding the supplement food in order to minimize the possible error due to different gut fills. Liveweight gain(LWG) was calculated by the difference method (Bailey et al,1958) which is defined as:

$$\frac{\text{LW at time } t2 - \text{LW at time } t1}{t2 - t1}$$

2.3.2 Chemical analysis of the food and faeces

2.3.2.1 Food

Samples of milk and concentrates (50 gm) were obtained daily and then pooled to obtain a composite sample for each paddock. The samples were ground through a 1 mm mesh and kept in air-tight plastic bottles.

Herbage samples were plucked by hand to simulate that grazed by calves. The herbage samples (200 gm) were taken once from every paddock prior to grazing and kept at -17°C before they were freeze-dried. After being dried, the samples were ground through a 1 mm mesh and kept in air-tight plastic bottles.

Milk,concentrate and herbage were analysed for DM contents,nitrogen contents, gross energy contents and ash contents. In addition herbage and concentrates were analysed for *in vitro* digestibility and PEG contents respectively (see Table 2.3).

Table 2.3 Analyses and methods used in the experiment

	Determination	method used
1	DM content	force draught oven for 12 hours at 105°C(A.O.A.C,1984)
2	Nitrogen content	Macro-Kjeldahl method(A.O.A.C,1984)
3	Gross energy(GE) content	Calorimetric bomb(A.O.A.C,1984)
4	Ash content	muffle furnace 550°C for over night(A.O.A.C,1984)
5	*In vitro* digestibility	Cellulase method(Roughan and Holland,1977)
6	PEG content	Turbidimetric method (Hyden,1956 and Ulyatt,1964)
7	Cr content	Atomic absorption spectro-photometry (Willium,*et al* (1962)

2.3.2.2 Faeces

Faecal samples were obtained from each calf by grab sampling daily after feeding and were then mixed "within calves" for each paddock as composite samples. A 24 hour gap between feed and faecal sampling was adopted to allow for passage of food residues through calves. The composite faecal samples were dried in a force drought oven for 48 hour at 76°C (140°F). Dry faeces were ground through a 1 mm mesh and stored in air-tight plastic bottles. All faecal samples were analysed for DM content, ash content, PEG content and Cr content (see Table 2.3). One composite sample for each calf was also mixed from faecal samples and these samples were analysed for gross energy contents.

2.3.3 Intake

Milk and concentrate supplements were offered to calves, in their respective treatments, once a day at 0930-1030 h. Milk was fed by teats attached to a drum. Concentrates were fed from a covered food bin. The amount of milk and concentrates offered each day was calculated from the number of calves in each treatment at any one time. Food refusals were weighed and recorded. The amount of food refused was added at the next feeding, therefore energy and protein intakes were approximately equal on average for the supplemented groups. In period III 1 kg of concentrate was fed to calves daily for 4-5 weeks according to the existing rearing system used on the No 1 dairy farm for weaned calves grazing pasture.

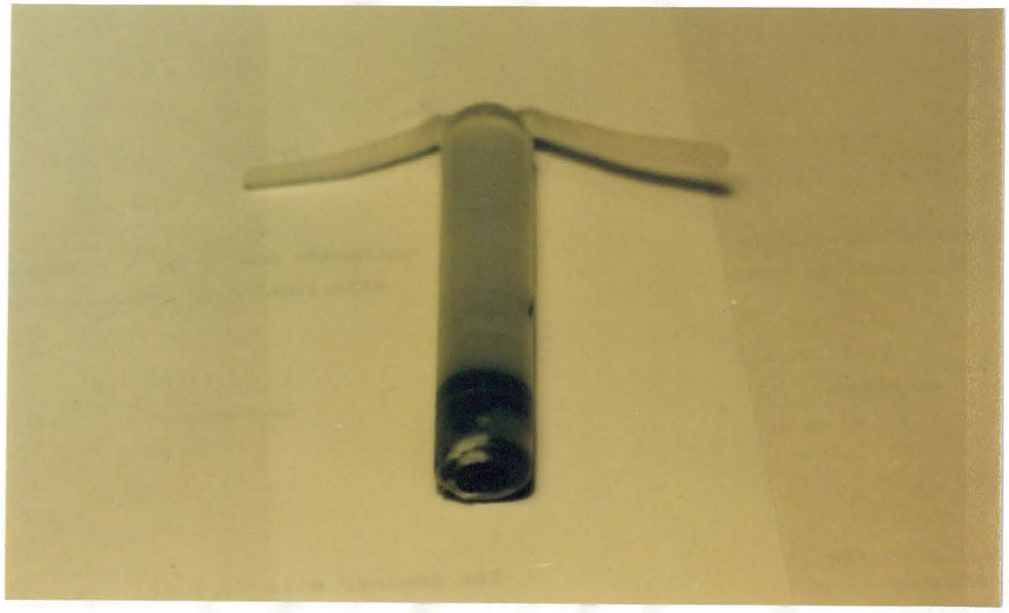
During period ll calves at any one time were grazing in the same paddock and the grazing interval varied from 4-7 days according to herbage yield and number of calves in each paddock. Herbage dry matter yields were measured weekly. Calves were leniently grazed pasture therefore they would be able to select high quality pasture. In period III, calves from all treatments were grazed together, but with female calves on No 1 dairy farm and male calves on a neighbouring sheep farm (Keebles).

The DM intake of grass and supplements consumed by individual calves were estimated indirectly using faecal markers and appropriate digestibility coefficients, as follows.

$$\text{Faecal DM output (g/d)} = \frac{\text{Cr excreted}^{*}\text{ (g/d)}}{\text{Cr content in faeces DM (g/g)}} \qquad \text{(Eq 1)}$$

$$\text{Dry matter intake (g/d)} = \frac{\text{faecal DM output (g/d)}}{\text{1-digestibility}} \qquad \text{(Eq 2)}$$

* Obtained in indoor experiment



Picture 1 The photograph shows CRD

Faecal DM output was estimated from the Chromium concentration (Cr)in the faeces of individual calves by the equation (1)above. The Cr was administered by the use of "controlled release devices" (CRD) which maintain a steady and prolonged release of Cr into the rumen of the calves. The CRDs were inserted into each calf by plastic tube 3-5 days prior to the start of period II. The rate of Cr excreted was obtained from a parallel indoor experiment, involving similar calves and treatments (Kassano,1987). He found that the Cr excretion rate varied slightly for different supplement groups($P<.08$) as shown

in Table 2.4 and these rates were used in the current experiment to calculate faecal outputs.

Table 2.4 Chromium excreted rates from total collection, indoors (Kassano, 1987)

Treatment	Cr release (g/d) mean(se)
S	0.138288 (0.01)
P	0.118376 (0.02)
L	0.101436 (0.01)
G	0.136200 (0.01)

The measured Cr concentrations in faeces were corrected for the concentration of Cr present prior to the use of the CRDs. There was an average of 19.5 ug Cr/g faecal DM present in 20 samples of faeces which would have been derived from the herbage or from soil contamination.

Polyethylene glycol (PEG,molecular weight 3350) was used as a marker to determine the amount of "dry" supplements consumed. PEG was mixed into the soya bean and milk powder mixes at a concentration of 0.5%. A 1% concentration of PEG was used for the carbohydrate mix because of the small amounts offered to each calf.

The intake of dry supplements by individual calves was estimated from the relative amount of PEG in faeces, and by apportioning the measured disappearance of food (within treatments and paddocks) on the basis of their total excretion of PEG calculated from the faecal DM outputs. For treatment L, the milk intake of individual calves was assumed to be 0.52kg (powder) daily throughout period II. Faster drinkers may have actually consumed a little more than those that suckled slower.

Some difficulty was encountered in deciding the most appropriate digestibility coefficients to use for the grazing calves. It was intended that the indoor experiment of Kassano

would provide digestibility estimates at different levels of supplement intake, but unfortunately the (DM) digestibility of the pasture (0.74) fed to calves indoors was lower than that available to the grazing calves (0.81, Table3.3). In addition there was clear evidence from the indoor experiment that the P supplement reduced the digestibility of the herbage consumed. There was no indication of a similar interaction when the milk powder was fed in a liquid form (L treatment) nor from the soya bean supplement (see Table 2.5).

Table 2.5 Actual and expected (DM) digestibilities of 50:50 supplement and herbage rations (Kassano,1987)

	Treatments					
	S		P		L	
	Expected	Actual	Expected	Actual	Expected	Actual
Herbage	*0.74	-	0.74	-	0.74	-
Supplement	0.85	-	0.92	-	0.92	-
Supplement + herbage	0.795	0.790	0.830	0.790	0.830	0.830

* Actual mean for herbage fed calves

The Kassano data indicated that the P supplement, when fed at 50% of the diet, reduced the digestibility of the ration by approximately 44% of the difference between the "expected" (or mean) digestibility, and the actual digestibility of herbage alone. While the digestibilities of the "grazed" herbages and the powdered milk supplement in the present experiment were much more similar, it was considered wise to assume that the digestibility of the combined ration would be lowered to the same relative extent as occured indoors. Thus the digestibility of a 50:50 ration of powdered milk (digestibility 0.92) and grazed herbage (digestibility 0.81) was assumed to be 0.840 rather than the mean "expected"digestibility of 0.865.

The expected faecal outputs from the estimated intakes of supplements were calculated using the "feeding standard"

digestibilities (shown in Table 2.5), and the faecal outputs from herbage for individual calves were determined by difference (ie total faecal output - faecal output from supplements).

The intake of herbage was calculated using equation 2 assuming the in vitro digestibilties (from individual paddocks) applied for the S and L treatments,while slightly reduced digestibility values as indicated above, were assumed to be applicable for the P treatment group calves.

The digestible energy (DE) intakes of individual calves were calculated from the total energy intakes of concentrate supplements and herbage less the total energy of faeces. Metabolisable energy (ME) intakes were calculated from the equation of ME = 0.82*DE (Blaxter et al,1966)

2.4 STATISTICAL ANALYSIS

The effects of the different supplements upon herbage intake, and weight gain were investigated by analysis of variance method and Duncan Multiple Range Test was used to compare the significance of differences between individual means.

The statistical analysis was carried out by using the SPSSx and SAS program.

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

*** Significant difference at the Probability $\leq$ 0.001
** Significant difference at the Probability $\leq$ 0.01
* Significant difference at the Probability $\leq$ 0.05
NS Not significant difference.

CHAPTER 3

RESULTS

3.1 FEED QUALITY

3.1.1 Supplements

The compositions (dry matter (DM), crude protein (CP), ash and gross energy (GE)) of the supplements fed during the experimental Period (Period II) are shown in Table 3.1.

Table 3.1 The mean composition of supplements (se of mean)

	DM (%)	CP (% DM)	ASH (% DM)	GE (MJ/KgDM)	ME (MJ/kgDM)	q
S	88.1(0.01)	22.8(0.13)	4.5(0.06)	18.9	13.2	0.70
P	92.0(0.06)	26.5(0.13)	6.1(0.01)	20.6	15.6	0.76
L[1]	92.8	26.7	5.7	21.5	16.2	0.75
CHO	88.5(0.06)	12.9(0.11)	3.0(0.04)	18.6		
Milk	94.7(0.28)	32.4(0.33)	6.9(0.01)	22.6		

where S = Soya bean, P = Powered milk, L = Liquid milk

1 Values were calculated from the individual components (milk and carbohydrate mix (CHO)) shown in the last two lines of the Table.

q is metabolisability (ME/GE)

The metabolisable energy (ME) concentration of the supplements in Table 3.1 were those estimated from the gross energy GE values and assuming digestibility (for energy) of 0.85, 0.92 and 0.92 for the S, P and L supplements respectively (MAFF,1977), and that ME=DE*0.82 (Blaxter et al,1966).

The average daily amounts of "nutrients" offered in the form of supplements to individual calves (over the whole of Period II) in terms of dry matter, crude protein, organic matter, gross energy and ME are given in Table 3.2.

Table 3.2 Quantities of nutrients offered to individual calves (per day) in supplements

	as fed (g)	dry matter (g)	crude protein (g)	organic matter (g)	gross energy (MJ)	ME[1/] (MJ)
S	1000	881.30	200.85	841.73	16.67	11.6
P	750	690.08	182.80	647.78	14.23	10.8
L	750	696.06	185.64	656.19	14.93	11.3

[1/] Calculated using ME data from Table 3.1

3.1.2 Herbage

Hand-plucked samples were taken from the twelve paddocks used during the experiment (Period II) and mean values for some aspects of nutritive value as well as minimum and maximum values for individual paddocks are presented in Table 3.3.

Table 3.3 Some chemical characteristics and DDM% of herbage from 12 individual paddocks

	mean(SE)[1/]	Min.	Max.
Crude protein (%)	29.4(0.4)	26.9	31.8
Ash (%)	11.0(0.2)	10.0	12.1
Gross energy (MJ/kgDM)	19.9(0.1)	19.2	20.5
In vitro DDM (%)	81.3(0.3)	79.9	88.2
ME (MJ/kgDM)	10.2 [2/]		
metabolisability (q,ME/GE)	0.51		

1/ SE = Standard error 2/ from Holmes and Wilson(1984)

The hand-plucked samples simulated herbage selected by the grazing calves. In this experiment most calves appeared to select the tips of grass leaves which were 5-10 cms long. A few calves consumed white clover in addition to grass but the time at which clover consumption commenced varied considerably between individual animals.

The pre-grazing herbage mass ranged from 1412-3259 kg DM/ha and the number of calves grazing in 2 ha paddocks varied from 6-32 calves. The liveweight of calves varied from 60-93 kg during Period II. Therefore the herbage allowance was at least 949 g/kg liveweight before grazing.

3.2 FEED INTAKE

3.2.1 Dry Matter Intakes

During the 35 days of the experimental period (Period II), calves in treatment S, P and L were offered 1 kg of soya bean mix, 0.75 Kg milk powder mix, and 0.23 Kg carbohydrate together with liquid milk (0.52 Kg milk powder) respectively on a daily basis. The mean amounts of nutrients offered on the dry matter basis are given in Table 3.2.

Faecal outputs (and intakes) were only estimated for days 5-30 during Period II. This was because the CRD units took 7-10 days to start releasing a constant output of marker and 29 of the 32 calves lost their units towards the end of the experimental period. Intakes could not be estimated from some calves because of early expulsion of the CRD units.

TABLE 3.4 Average dry matter intake of food during days 6-30 during Period II

	Treatment				Significance
	S	P	L	G	
Days	25	25	25	25	
Number of calves	6	6	6	5	
	mean(se)	mean(se)	mean(se)	mean(se)	
SupplementDM (g/calf/d)	847.1^{a}(74.5)	657.1^{a}(141.5)	668.5^{a}(35.4)	-	NS(0.24)
Herbage DM (g/calf/d)	883.7^{b}(55.3)	512.4^{c}(106.4)	699.7^{bc}(64.8)	1387.9^{a}(105.6)	***(0.001)
Total DM (g/calf/d)	1730.8^{a}(42.6)	1169.5^{b}(101.7)	1368.2^{b}(78.2)	1387.9^{b}(105.6)	***(0.004)
Total OM (g/calf/d)	1595.3^{a}(41.4)	1072.7^{b}(95.2)	1252.8^{b}(70.7)	1235.0^{b}(94.0)	***(0.003)
Substitution rate	0.72^{b}(0.07)	1.82^{a}(0.31)	1.09^{b}(0.13)	-	**(0.01)
Total DM (g/KgLW/d)	23.9^{a}(0.8)	16.2^{c}(1.0)	18.2^{bc}(0.8)	20.0^{b}(1.1)	***(0.001)
Total OM (g/KgLW/d)	22.0^{a}(0.8)	14.9^{b}(1.0)	16.7^{b}(0.7)	17.8^{b}(1.0)	***(0.001)

The estimates for the intake of calves in the four treatments groups during the "intake measurement period" (day 6-30) are given in Table 3.4 Estimated intakes of concentrate were very similar to the mean amounts offered (Table 3.2) during the whole of Period II. However the mean intakes were not significantly different because of considerable variation between the intakes of individual animals within groups. The supplement intake of the calves fed powdered milk were particularly variable as judged by the standard error.

All supplements significantly depressed the intake of herbage ($P<0.001$). The intake of herbage by individual "supplemented" calves was inversely related to supplement (DM) intake ($r= 0.71$, $P<0.0001$). Herbage intakes within groups were very variable within the P and G groups. Among the supplemented groups, the mean herbage intake of the S group was higher than for the milk powder group (P) but not significantly higher than the L group. Form of milk supplement (P and L) had no significant effect on herbage intake of calves.

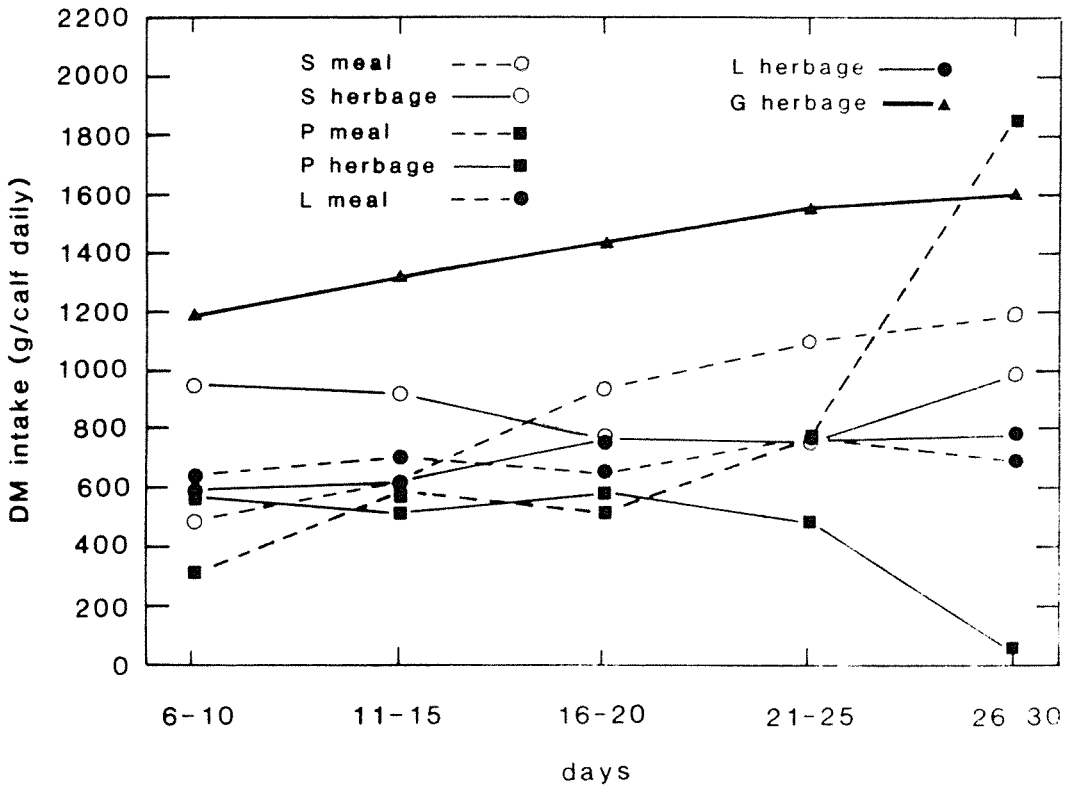
The extent of replacement of herbage with concentrate was measured by the substitution rate and the G treatment was regarded as the expected maximum intake. The substitution rates for individual calves were negatively related to herbage DM intake ($r=-0.76$, $P<0.0001$) and total DM intake ($r=-0.59$, $P<0.01$).The higher herbage substitution rate, the lower the herbage DM and the total DM intakes.

The mean substitution rate for the P group was significantly higher than those for the S and L groups ($P<0.05$).

Total DM (and OM) intakes expressed as g/calf or per unit liveweight per day, were highest for the calves fed S supplement ($P<0.001$) and the mean values for those fed powdered milk were consistently the lowest. While the

total intake of L calves were slightly higher than those for P calves they did not differ significantly. The data showed that supplement DM intakes were positively related to total DM intake ($r=0.37$, $P<0.08$).The S supplement significantly increased the total DM intake of calves above those for the remaining treatments.

Fig 3.1 Herbage and meal intake during Period II



The intake of supplements and herbage varied over the measurement period and these changes are illustrated in Figure 3.1. Supplement intake increased progressively with time. This was most marked in the S and P treatments and herbage intake was depressed as a result. Herbage intake in L treatment calves were relatively constant whereas the G treatment showed a more marked upward trend.

Total dry matter intake/kg LW did not differ significantly between male and female calves (Table 3.5).

Table 3.5 Mean dry matter intake per kg LW of male and female calves (g DM/kgLW)

	Sex		
	male	female	significance
DM intake	19.0(1.1)	19.3(1.0)	NS(0.85)

3.2.2 Energy and Crude Protein Intakes

The metabolisable energy (ME) and Crude protein (CP) intake per calf for treatment groups were compared on an absolute,and on a metabolic body weight basis. The average metabolic weight for each treatment was calculated from the liveweight of calves during Period II. The average liveweight and metabolic weight of each treatment group of calves are shown in Table 3.6.

ME and CP intake of calves for each treatment group are shown in Table 3.7. The ME intakes of S treatment calves were significantly ($P<0.05$) higher than for milk powder fed calves (P) but did not differ significantly from L calves. The ME intake of S supplement group was significantly higher than the non-supplemented calves (G), whereas calves with milk supplement (P and L) did not differ significantly from the non-supplemented calves (G).

TABLE 3.6 The average live weight (LW) and metabolic weight (MW) of calves

	treatment				
	S	P	L	G	significance
LW (kg)	73.5(0.9)	71.6(2.5)	75.3(1.2)	70.1(1.3)	NS(0.11)
MW ($kg^{0.75}$)	25.1(0.2)	24.6(0.6)	25.6(0.3)	24.2(0.3)	NS(0.11)

TABLE 3.7 Comparison ME and CP intake between treatments

	treatment				
	S	P	L	G	Significance
ME (MJ/calfdaily)	22.4^{a}(0.6)	16.1^{b}(1.4)	19.9^{ab}(1.0)	18.1^{b}(1.5)	**(0.01)
CP (g/calfdaily)	452.5^{a}(9.9)	324.5^{b}(27.3)	383.7^{ab}(22.4)	407.5^{a}(31.0)	**(0.01)
ME : CP (kJ/g)	49.5^{b}(0.5)	49.4^{b}(0.9)	52.1^{a}(0.5)	44.3^{c}(0.4)	***(0.001)
ME ($MJ/kg^{0.75}/d$)	0.90^{a}(0.1)	0.65^{b}(0.1)	0.78^{ab}(0.1)	0.75^{b}(0.1)	**(0.01)
CP ($g/kg^{0.75}/d$)	18.2^{a}(0.5)	13.1^{c}(0.8)	15.0^{bc}(0.7)	16.9^{ab}(1.0)	**(0.01)

The CP intake of the P supplemented calves did not differ significantly ($P<0.05$) from (L) calves, but they were significantly lower than those for the S and G calves. On the other hand S, L and G means were not significantly different.

The ratio ME intake to CP intake was significantly higher ($P<0.001$) for the L treatment whereas the G treatment was significantly lower ($P<0.001$) than the other treatments (S and P treatments).

The ME and CP intakes, and the ratios ME:CP for male and female calves did not differ significantly (Table 3.8).

TABLE 3.8 Comparison of ME and CP intakes of male and female calves

	Sex		
	male	female	significance
ME ($MJ/kg^{0.75}/d$)	0.78(0.1)	0.77(0.1)	NS (0.887)
CP ($g/kg^{0.75}/d$)	15.8(0.8)	15.7(0.8)	NS (0.915)
ME : CP (kJ/g)	49.0(0.9)	49.0(0.9)	NS (0.989)

3.2.3 Water intake

The average water intake per calf per day for each treatment group and those during the first week of Period II are shown in Table 3.9. They were calculated from the amount of total water consumed by each treatment group during Period II divided by the number of calf-days. Water intakes during the first week were consistently higher than the average water intake in treatment S and P but they remained the same in L treatment. In contrast,in the G treatment, water intake in the first week was less than the for whole period.

Table 3.9 Average water intakes (l/calf daily)

	treatment			
	S	P	L	G
First week	13.6	12.6	9.4*	5.4
Whole period	8.6	7.6	9.3*	7.7

* Water intake included milk volume

3.3 CALF PERFORMANCE

3.3.1 Live weight

The liveweight of calves at the start of the experiment (Period II), at about 5 weeks of age, were not significantly different between treatments (Table 3.10). All supplement treatments had positive effects on live weight at the end of the comparison period (Period II) at about 10 weeks of age. However only the liveweights of the S and L supplemented calves were significantly higher than that for the non-supplemented calves (group G). Among the supplemented calves, the liveweight of L calves was significantly ($P<0.05$) greater than that for P but not greater than for the S group.

By the end of Period III, at 33 weeks, the S and L calves were significantly heavier than the P calves but only the difference between the L and P calves had persisted from the experimental period.

Table 3.10 Average liveweight of calves in treatment groups

Treatment	Live weight (kg)		
	5 weeks	10 weeks	33 weeks
S	64.6(0.9)	82.4^{ab}(1.1)	231.4^{a}(4.8)
P	63.7(1.2)	79.9^{bc}(3.3)	212.5^{b}(8.9)
L	63.8(1.4)	86.7^{a}(1.5)	228.8^{a}(7.4)
G	65.6(1.0)	74.5^{c}(2.0)	217.1^{ab}(5.7)
Significance	NS(0.695)	**(0.003)	*(0.044)

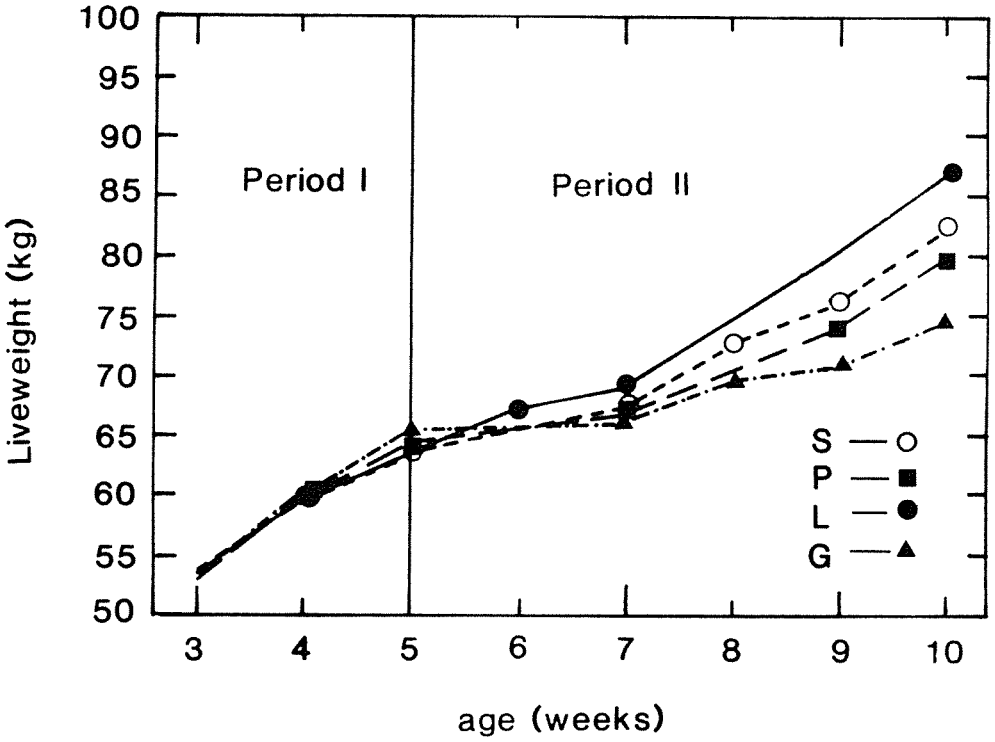
A comparison of the liveweight of calves over time during Periods I and II is made in Table 3.11 and graphically in Figure 3.2.

The differences in live weight means between treatments appeared to emerge mainly in the last two weeks of Period II.

Table 3.11 Comparison of weekly liveweights during Period I and II

Period	age (weeks)	Treatment				Significance
		S	P	L	G	
I	3	53.9	53.0	53.6	53.4	NS(0.93)
	4	59.9	59.7	59.3	60.7	NS(0.87)
	5	64.6	63.7	63.8	65.6	NS(0.69)
	6	65.4	65.4	67.3	65.8	NS(0.71)
II	7	67.5	66.9	69.1	66.3	NS(0.65)
	8	72.8	70.5	74.6	69.6	NS(0.20)
	9	76.4^{ab}	74.2^{b}	80.4^{a}	70.9^{b}	**(0.01)
	10	82.4^{ab}	79.9^{bc}	86.7^{a}	74.6^{c}	**(0.003)

Fig 3.2 Liveweight during Period I and II

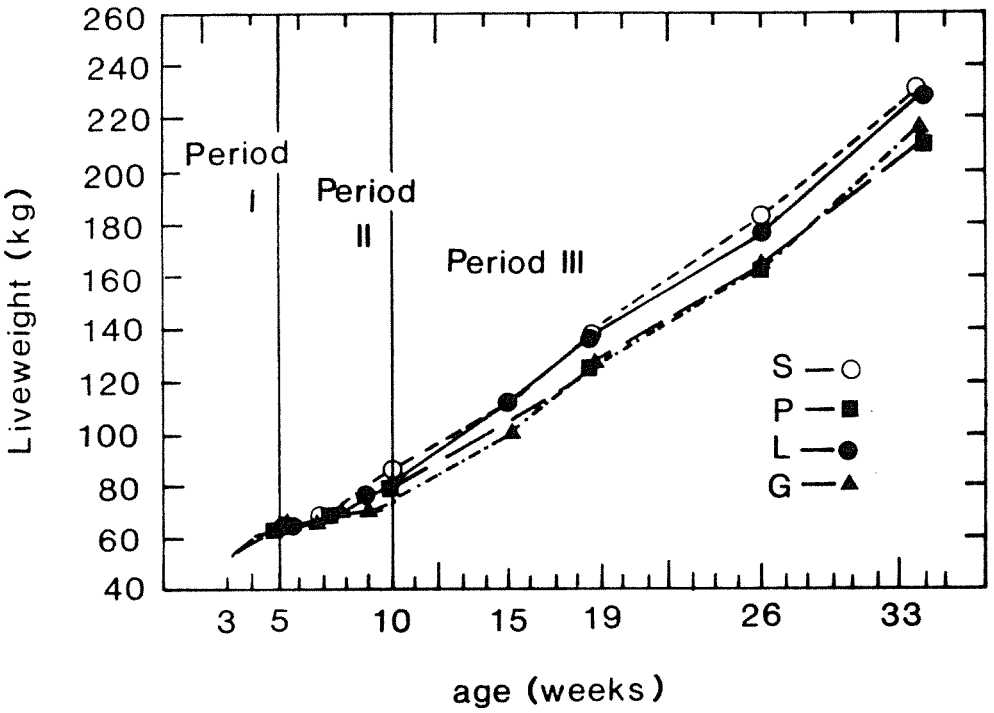


Comparisons of the liveweight of calves over time during Period III are presented in Table 3.12 and in Figure 3.3. The liveweights of S and G calves increased more rapidly than L and P calves,especially from 19 weeks of age onward. At 33 weeks of age, therefore, there is no significant difference between calves with supplement and those without supplement. Among the supplemented calves,the liveweight of P calves were significantly lower than S and L calves.

Table 3.12 Comparison of liveweight means (kg) at different age during Period III

age (weeks)	treatment S	P	L	G	Significance
15	111.9^{a}	104.4^{b}	113.5^{a}	101.3^{b}	** (0.003)
19	141.4^{a}	126.8^{b}	139.9^{a}	127.8^{b}	* (0.030)
26	182.3^{a}	161.8^{b}	176.4^{ab}	163.6^{b}	** (0.016)
33	231.4^{a}	212.5^{b}	228.8^{a}	217.1^{ab}	* (0.044)

Fig 3.3 Liveweight during Period I,II,and III



The live weights of male and female calves were not significantly different at the end of Period I (5 weeks of age), Period II (10 weeks of age) or Period III (33 weeks of age) (Table 3.13).

Table 3.13 Comparison of means liveweights (kg) for male and female calves.

	age (weeks)		
sex	5	10	33
Male	63.8(0.9)	79.5(1.6)	223.1(5.5)
Female	65.1(0.8)	82.4(1.95)	221.8(4.7)
Significance	NS(0.29)	NS(0.26)	NS(0.85)

3.3.2 Growth Rate

The average growth rates over Periods I,II and III are shown in Tables 3.14 and the week to week growth rates in Tables 3.15 ,3.16 and Figures 3.4 and 3.5. The average growth rates differed significantly in Period II but were not different in Periods I and III. In Period II,the growth rates for calves with supplement (S,P,L) were significantly greater than calves without supplement(G). Among calves with supplement ,the growth rates of calves in treatment L were significantly ($P<0.05$) greater than those for treatments S and P while the growth rate in treatments S and P calves were not significantly different.

Table 3.14 The average growth rates for experimental periods.

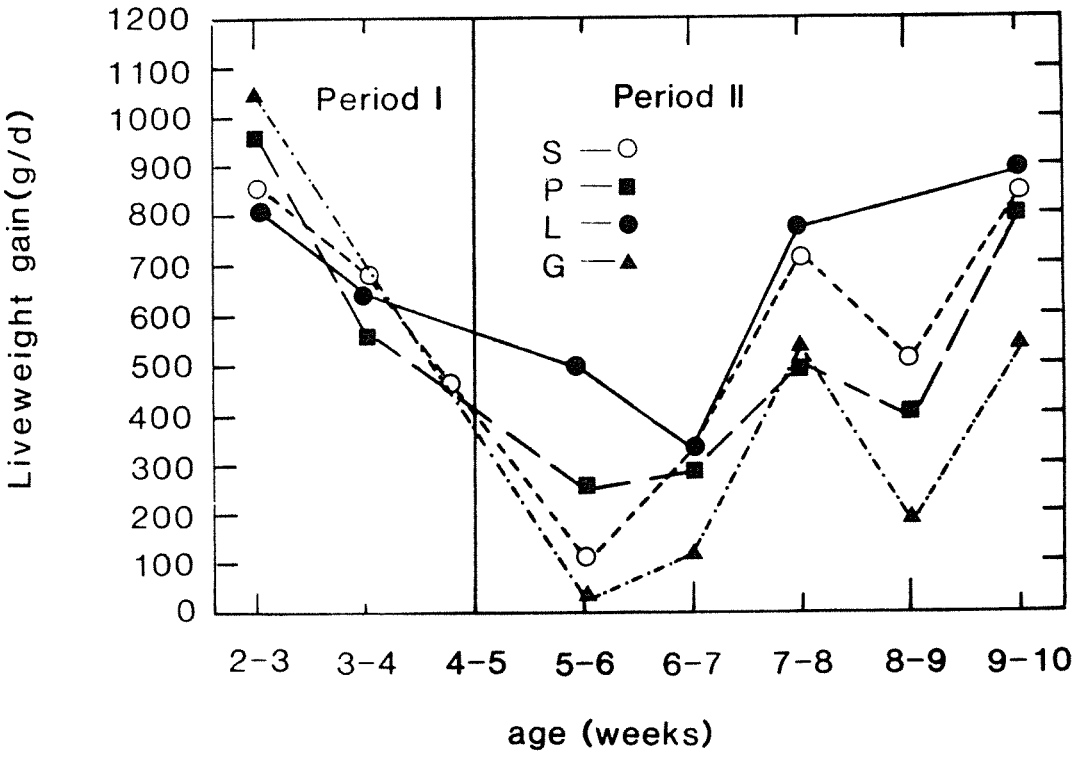
Treatment	Growth rate (g/d) Period I	Period II	Period III
S	767.9(75.2)	507.1[b](32.5)	900.3(28.0)
P	767.0(85.6)	473.5[b](53.5)	815.1(41.2)
L	727.7(62.2)	653.6[a](41.9)	864.9(33.6)
G	870.5(84.6)	257.1[c](49.3)	873.4(20.4)
Significance	NS(0.42)	***(0.001)	NS(0.32)

Through Period II, the weekly growth rates of treatment L calves were generally higher than for those in treatments S,P and G (see Table 3.15 and Figure 3.4). The growth rates for other treatments did not differ significantly. Growth rates during the first week of Period II were dropped in all treatment groups. The supplemented group (S,P,L) particularly those with milk were less affected than those receiving herbage alone. Again during week 8 -9 growth rates decreased compared to the previous week with the exception of L supplemented calves.

Table 3.15 Comparison of weekly growth rate (g/d) during Periods I and II.

Period	age (weeks)	Treatment S	P	L	G	Significance
I	3-4	857.1	962.5	812.5	1044.6	NS(0.27)
	4-5	678.6	571.4	642.9	696.4	NS(0.79)
	5-6	107.1^{b}	250.0^{ab}	491.1^{a}	26.8^{b}	**(0.01)
	6-7	336.7	285.7	336.7	122.5	NS(0.07)
II	7-8	724.5	500.0	775.5	530.6	NS(0.46)
	8-9	517.9^{b}	387.8^{ab}	839.3^{a}	178.6^{b}	*(0.03)
	9-10	857.1	806.1	892.9	526.8	NS(0.26)

Fig 3.4 Liveweight gain during Period I and II



The average growth rates in Period III are shown in Table 3.16 and Figure 3.5. During Period III, the growth rates were not significantly different between the treatment groups throughout the period. However, the

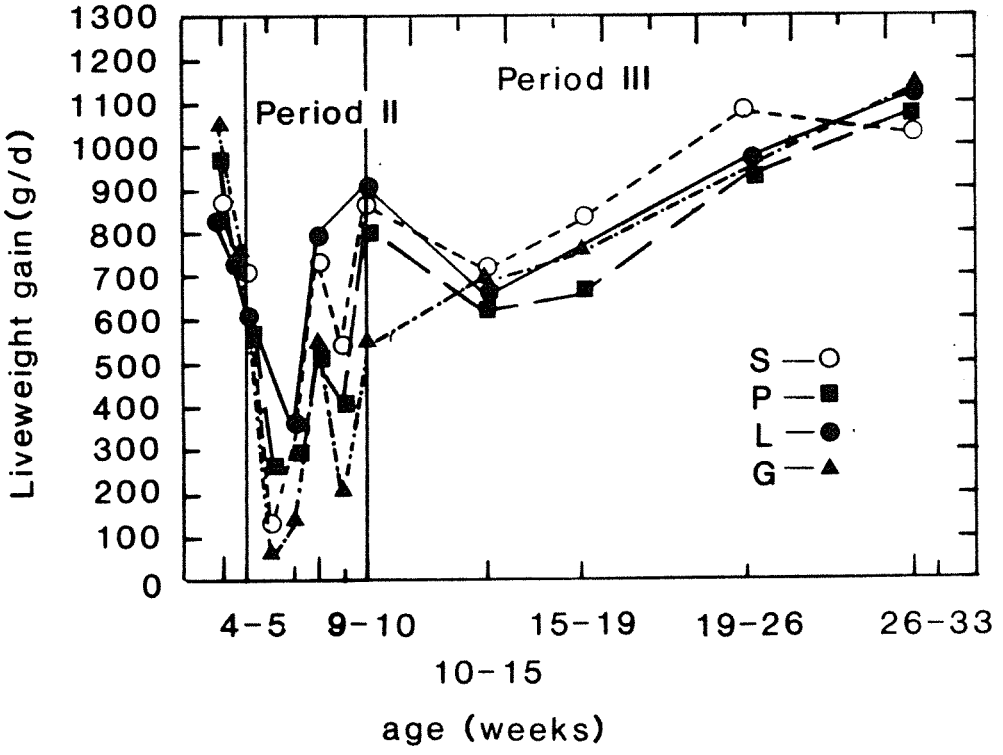
growth rates during 10-15 weeks of age,with the exception of those in treatment G,were dropped compared to those in the last week of the pevious period.

Liveweight gains during Period III has no relationship with both liveweight gain during supplemental period and final liveweight result from supplementation.

Table 3.16 Comparison of means growth rate (g/d) for the last week of Period II and during Period III.

age (weeks)	Treatment S	P	L	G	Significance
9-10	857.1	806.1	892.9	526.8	NS(0.26)
10-15	698.5	607.7	643.8	669.7	NS(0.76)
15-19	815.3	648.1	752.0	733.1	NS(0.19)
19-26	1066.2	915.6	959.1	929.3	NS(0.54)
26-33	1021.9	1066.7	1098.6	1106.3	NS(0.86)

Fig 3.5 Liveweight gain during Period I,II &III



The growth rates of male and female calves during Periods I and II were not significantly different. However during the Period III, the growth rates of female calves were significantly higher than male calves.

Table 3.17 Comparison of means growth rates (g/d) of male and female calves during Period I,II and III.

	Period		
	I	II	III
Male	792.4(46.4)	449.1(51.3)	834.4(24.3)
Female	774.1(61.8)	498.1(44.1)	897.6(16.7)
Significance	NS (0.81)	NS (0.48)	* (0.04)

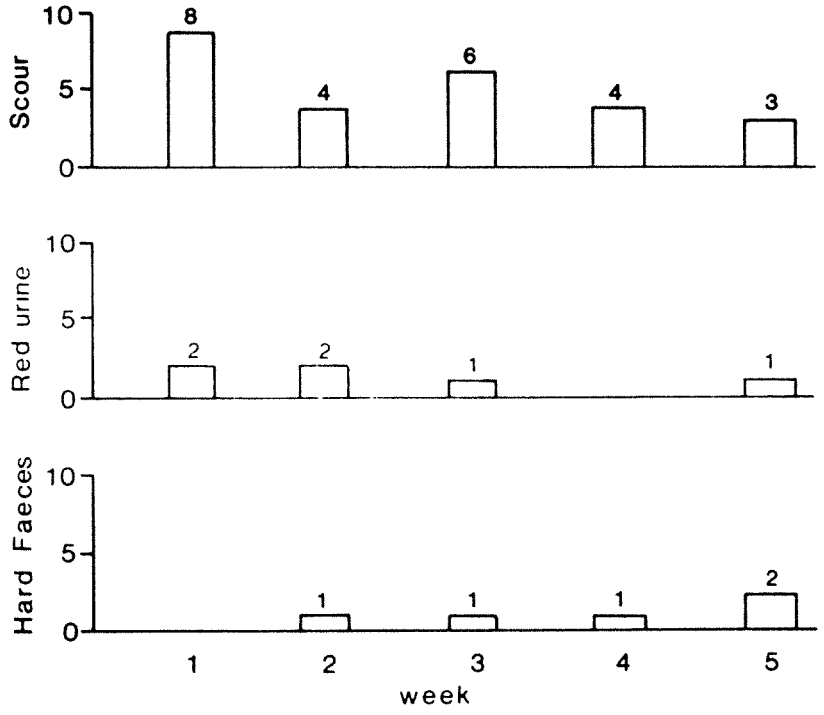
3.4 ANIMAL HEALTH

During Period II, some calves showed a variety of symptoms of ill health and the incidence rate for each treatment group is summarized in Table 3.18 and timing of some occurrences in Figure 3.6. Scouring was the most common

Table 3.18 Number of calves showing sign of illness during Period II.

Cases	Treatment			
	S	P	L	G
Scouring	5	2	5	5
Red urine	-	2	-	1
Hard faeces	-	2	-	-
Lump in neck	-	1	-	-
Inappetance	-	1	-	1
Bloat	-	-	-	1
Death	-	-	-	1
Out of treatment	-	1	-	-

Fig. 3.6 Number of incidences of illness week by week during Period II



complaint particularly in the first week. It occurred in all treatment groups although a little less frequently in the P group. All calves recovered within 2 days following treatment with "Scour Ban". Apart from calves with scours only the P and G groups showed other signs of ill health. The calves receiving the powdered milk mix suffered from a number of complaints which were very difficult to explain. These included blood in urine,hard faeces and one with a swelling in the neck. In addition one calf in this group was removed from the treatment after 2 weeks due to excessive weight loss and inappetance.(The results for this group are therefore based on 7 calves). The main problem with the herbage only calves (G) was that they suffered from a weaning check (see Table 3.15) which was severe enough to lead to the loss of one calf. This one was however replaced with another animal. Signs of inappetance,red urine and bloat also occurred in this treatment group.

3.5 FEED EFFICIENCY

3.5.1 The relationship of food intake to calf performance during Period II

Higher intake of supplement consumption were associated with higher liveweight gains ($r=0.65$, $P<0.001$) and final liveweights of calves ($r=0.55$, $P<0.01$). Herbage DM intake however were not closely related to liveweight or gain. Liveweight gain during Period II can be predicted approximately from the amount of supplement DM intake as shown in the following equation:

$$Y = 262.0 + 0.37\ (\pm 0.1)\ X \quad (R^2 = 0.43,\ P<0.001).$$

where Y is liveweight gain (g/d), X is daily supplement DM intake (g/calf)

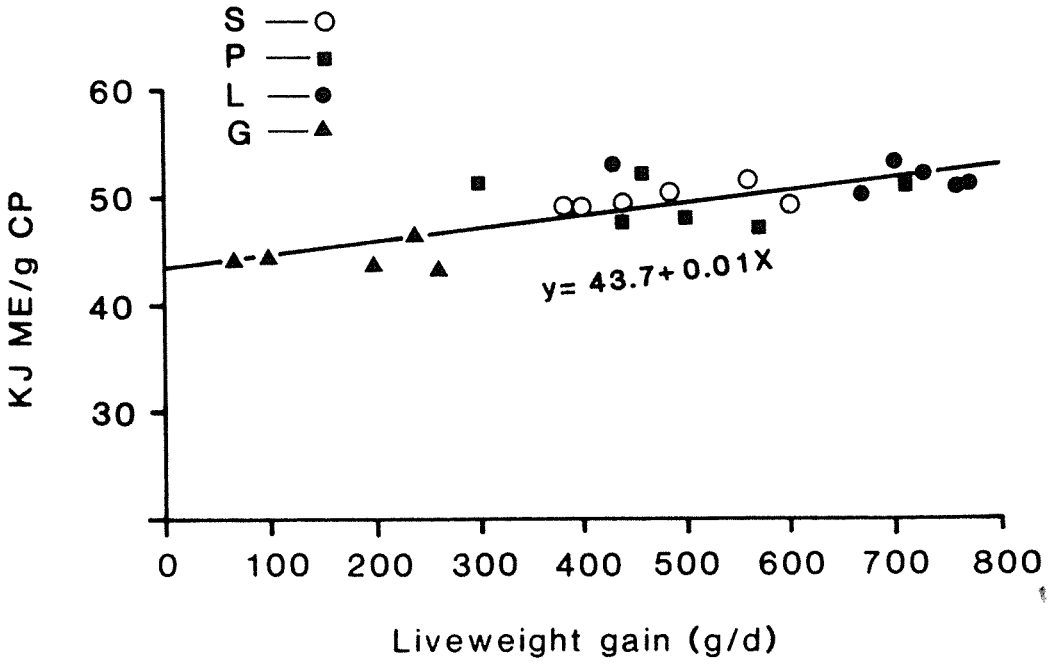
There was no overall significant relationship between ME (or CP) intake(s) and liveweight gain, but there was a highly significant relation between ME:CP ratio (KJME/g) and rate of gain. As the amount of concentrate consumed increased the ratio of ME to CP increased and the rate of gain increase also. The relationship between ME:CP ratio and growth rate was estimated from the pooled data for all four treatments and is shown in Figure 3.7 and the regression equation given in Table 3.19. The regression was highly significant and suggests that this ratio may be an important determinant of growth rate in calves.

Table 3.19 The relationship between ME : CP ratio and growth rate

Equation	R^2	significance
$Y = 43.71(\pm 1.08) + 0.011(\pm 0.002)X$	0.57	***(0.001)

where Y is ME:CP (KJ/g) and X is growth rate (g/d)

Fig. 3.7 Relationship between ME:CP ratio and liveweight gain during Period II



The liveweight gains were associated with ME and CP intakes as described by the following multiple regression equation:

$Y = 311.8+137.1(\pm 24.4)X_1-6.3(\pm 1.2)X_2$ ($R^2=0.62$, $P<0.0001$)

where Y is liveweight gain (g/calf), X_1 is daily ME intake (MJME/calf) and X_2 is daily CP intake (g/calf). From this equation a comparison of actual and estimated liveweight gain are shown in Table 3.20.

Table 3.20 Estimated and actual mean liveweight gains for four treatment groups during Period II

	S	P	L	G
Actual (g)	507.1	473.5	653.6	257.1
Estimated (g)	532.1	474.8	622.8	277.9
Difference from estimated	-25.0	-1.3	+31.8	-20.8

3.5.2 The relation of food intake during Period II and calves performance during Period III

The liveweight gains of calves during Period III tended to be related to total DM intake ($r=0.39$, $P<0.07$) and herbage DM intake ($r=0.35$, $P<0.1$) but there was no relationship with the amount of supplement intake during Period II. Liveweight gain during Period III also had slight negative relationship ($r=-0.37$, $P<0.09$) with herbage substitution rate.

3.5.3 The estimation of ME requirements for calves during Period II

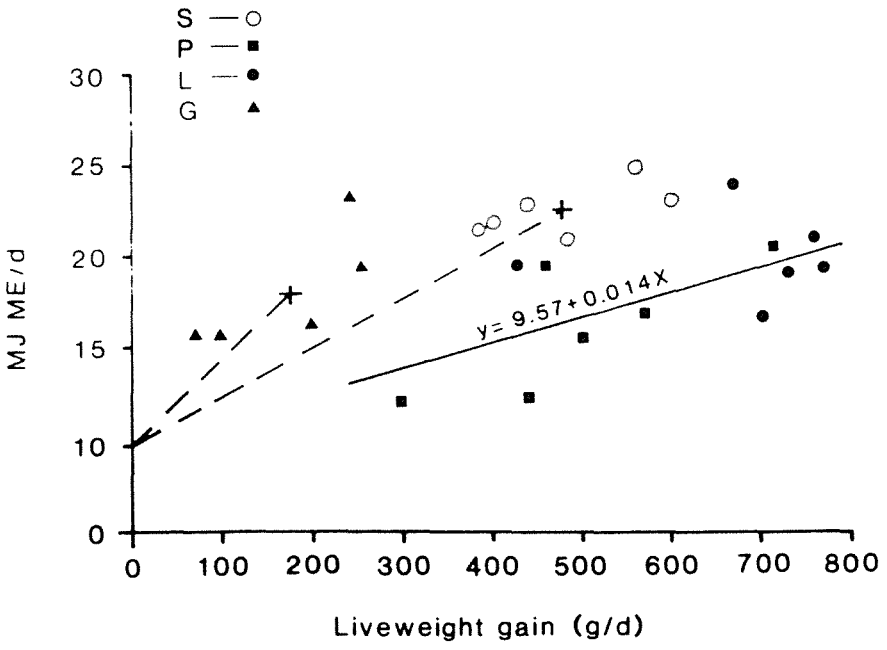
The relationship between total metabolisable energy intake per day (ME) (during days 6-30) and mean growth rate for individual calves during Period II is shown in

Figure 3.8. A regression relationship was estimated for P and L groups which recieved similar feed supplements and also appeared to have similar relation ships. The regression equation is given in Table 3.21. The regression with other treatments were not significant.

Table 3.21 Regression equations relating ME and growth rates

Equation	R^2	Significance
1. Feed with milk (P and L calves)		
$Y = 9.57(\pm 3.33) + 0.014(\pm 0.006)X$	0.40	*(0.02)
where Y is ME (MJ/calf daily and X is growth rate (g/d)		

Fig. 3.8 Relationship between ME and liveweight gain.



The constant values from the regression equation represents ME at zero growth rate,which is the ME requirement for maintenance. The average metabolisable

energy requirement for maintenance, of milk fed calves was thus 9.57 MJ/calf daily. The b value from the regression equation represents ME required for per unit increase in growth rate. ME required for one kg of liveweight gain for milk fed calves was 14 MJ daily. Assuming S and G calves require the same energy for maintenance (9.57 MJ/calf daily), the energy requirements above maintenance were calculated from the mean value of ME intake for each of the groups. The ME requirement above maintenance for S and G groups were 26.8 and 48.9 MJ/kg liveweight gain respectively.

CHAPTER 4

DISCUSSION

4.1 EFFECT OF SUPPLEMENT ON FOOD INTAKE

The results in this experiment showed that all supplements significantly depressed the herbage intake of young calves (5-10 weeks of age) (see Table 3.4). These results are agreement with those of Chamber (1961); Keane and Harte (1982);and Leaver (1973).Compared with the calves fed grass only (G), the daily herbage intakes per calf were significantly ($P < 0.05$) depressed by 39-63% by the different treatments. In older calves (14-30 weeks of age) fed milk and concentrate supplements, Keane and Harte (1982) found that daily herbage intake was depressed by 15-26%. The extent to which herbage intake is depressed may depend on the amount of supplement offered. Campling and Murdoch (1966) found that when only small quantities of concentrates were offered, the intake of roughages may be either unaffected by supplementation or increased if the roughage is of low digestibility. When larger amounts of concentrates were offered to a level where concentrate DM intakes accounted for 33 to 85% of total DM intake, intake of roughage was depressed (Leaver, 1973; Campling and Murdoch, 1966). Therefore the greater depression found in the present experiment may have been due to the fact that the supplement intakes were 49-56% of total intake whereas they were 24-31% in the experiment of Keane and Harte (1982).

The amount of herbage DM intake depressed per unit DM of supplement offered is termed herbage substitution rate. It was found in this experiment that herbage substitution rate for "milk" supplement groups (P and L) were generally higher than that for the S concentrate supplement. However the value for the P supplement was also significant higher ($P < 0.05$) than those for the L and S supplements (see Table 3.4). The average values for herbage substitution rate in this experiment,those from Keane and Harte (1982);and Chambers (1961) are summarized

in Table 4.1. The substitution rates for soya bean concentrate are similar but they vary for the milk supplements. It was found in the present experiment that herbage substitution rate ,during Period II,was negatively related to total DM intake and herbage DM intake. That is the higher the substitution rate, the lower the herbage DM intake and total DM intake (see section 3.2.1).

Table 4.1 Comparison of herbage substitution rate of supplements

supplement	age of calves	source of protein	substitution rate	herbage DM g /kgLW	total DM increase (%)
(1)					
concentrate	14-30	HCHO+soya bean meal	0.52	22.4	17
concentrate	14-30	soya bean meal	0.73	21.1	9.6
liquid milk	14-30	milk	0.58	21.9	10.9
powder milk	14-30	milk	0.59	22.4	10.6
(2)					
concentrate	2-11	ground nut	0.63	-	40
concentrate	2-11	ground nut +fish meal	0.58	-	29
(3)					
concentrate(S)	5-10	soya bean	0.72	12.0	25
concentrate +liquid milk(L)	5-10	milk	1.09	9.3	-1.4
concentrate(P)	5-10	milk	1.82	7.2	-15

(1) Keane and Harte (1982) (2) Chambers (1961) (3) present experiment

The results in this experiment (see Table 3.4) showed that among the supplemented calves (S,P,L), the S supplement resulted in a higher herbage DM intake than those for P and L

calves. Since the S supplement had a lower ME concentration than the P and L supplements (see Table 3.1). The ME concentration in the ration of S calves must have been lower than those for P and L calves. Herbage intake in addition to supplement intake for S calves may have been limited by the capacity of reticulorumen while those with P and L supplement may have been limited by energy requirement before DM intake (supplement and herbage) reached gut fill. Herbage intakes for calves with P supplement were slightly lower than those with L supplement. The lower intakes of the calves receiving P supplement may also have been associated with one or more of the health problems observed in this group or alternatively an undiagnosed problem such as rumen acidosis which may have resulted from the rapid fermentation of the milk powder (Roy,1980).

4.2 COMPARISON OF SUPPLEMENTS ON CALF PERFORMANCE

4.2.1 Supplemental period

The calves on grass alone received a weaning check and then gradually increased their rates of gain.The feeding of supplements (S,P,L) increased the liveweight gain of the young calves (5-10 weeks of age) grazing pasture. These results are in agreement with those of Gleeson (1971); Donnelly (1977) and Byford (1973) and alsothose of Keane and Harte (1982) who used 14-30 week old calves. The higher growth rate of supplemented calves was probably partly due to the higher DM digestibility of the supplements (85-92%) compared with pasture (81%) (see Table 2.5 and 3.3). In addition, the DM intake of supplemented calves were higher and it is possible that the intake of the calves fed pasture only was limited by the capacity of their recticulorumen. Byford (1973) showed that despite similarities in DM digestibilities which were approximately 76% for both the concentrate and grass,calves receiving concentrate supplement gained more liveweight than those fed pasture only (580 and 320 g/d).The major difference was that of intake, with the lower intake of grass associated with its greater bulk (Hodgson, 1971a).

In contrast, in an experiment with Ayrshire bull calves weaned at 8 weeks of age,onto either pasture only or pasture with a concentrate supplement until 20 weeks old, Castle and Walker (1959) found similar mean daily liveweight gains (559 and 609 g/d,respectively). The high growth rate of calves fed pasture (559 g/d) indicates that a high quality of pasture was used. In fact, Castle and Walker (1959) used regrowth pasture of 4-6 inches high which would be of high digestibility and hence result in a high DM intake comparable to concentrate fed calves.

Relatively low liveweight gains (257 g/d) were obtained from the grass fed calves in the current experiment, inspite of a high digestibility. Similarly Reid (1986) found that beef cattle (170-220 kg) grazing at the same pasture allowance ,grew faster in spring than in autumn/winter. He also found that allowances required for maintenance was lower in spring than in autumn/winter and potential growth rates in spring approximately double those in autumn. This is most likely to have been due to a low k_g value for the utilize of ME. MacRae et al (1985) found a difference in efficiency of utilisation of metabolisable energy for production, in absorption of non-amino N and total amino acids in the small intestine between spring and autumn havested pasture.

In this experiment,the L supplement calves had the highest liveweight gain among the supplemented calves (S,P,L) whereas that for the P calves was the lowest (but not significantly different from that for the S calves). The significant difference in liveweight gain between the four treatment groups occurred mainly during the first and the fourth weeks (8-9 weeks of age) of period II. During the first week of period II, all treatment calves except the liquid milk group may have suffered from a weaning stress. In this experiment calves were fed fresh milk at a high level (average 7 litre) during Period I, and a high level of milk fed to young calves was found to depress the herbage DM intake during the pre-weaning period and for three weeks after weaning by Wang et al (1985); Baker et al (1976); Baker and Barker (1978); and

Hodgson (1971e). Therefore liveweight gain for a few weeks after weaning may be limited by low herbage DM intake after weaning. This may be associated with oropharyngeal factors as well as the limitation of the eating behaviour (Hodgson,1971a,d). All the supplements and especially the "milk" treatments were highly digestible and consisted of small particles which would be expected to leave the rumen quickly. Liveweight gain of supplemented calves,particular those with milk (P and L) suffered less severely from the "weaning" stress (see Table 3.15). However, some ill health in P calves (see Table 3.18) may also have led to the lower liveweight gain than would be expected.

It was also found that the liveweight gains dropped again during 8-9 weeks of age (see Figure 3.4). This occurence was similar to that during the first week after weaning. The liveweight gain drop indicates that nutrients supplied relative to animal requirements were short. Hodgson (1971d) stated that oropharyngeal factors associated with the development of eating behaviour control the initial development of solid food intake. The increase in solid food intake after weaning was related to an increase in the time spent eating and ruminating, but later increases in food intake were achieved by an increase in the rate of DM intake per unit of time spent eating,with no further increase in eating time (Hodgson, 1971a). Both these changes probably accounted for the liveweight gain increases which occured during weeks 6-8 of age (see figure 3.4). The limitation of food intake by oropharyngeal factors has been reported (Hodgson,1971d) to continue for 4-6 weeks after weaning. It is thus possible that the lower gains recorded in 3 of the 4 treatment groups during weeks 8-9 were due to those factors especially as the requirements of the rapidly growing calves would have been increased by this age. By 10 weeks of age oropharyngeal factors may have become less important and growth rates again accelerated.

It can be concluded that a liquid milk supplement (L) with a high ME concentration and palatability could be used to overcome growth checks due to slow adjustment of calves

following weaning (eg Figure 3.4).

Including milk protein as the major protein source in concentrate supplement (P), slightly depressed liveweight gain in the present experiment compared to having soya bean as the major source of protein. However,other constituents such as milk lactose was also different in the two rations. Milk powder accounted for 69% of concentrate mixture (P) (see Table 2.2) or 42% of the mean total DM intake (see Table 3.4). A high level of dry milk in the ration may have reduced rumen digestion (mainly fibre) and hence accounted for the lower liveweight gain. Preston (1956) found that small amounts of dry milk in the ration increased the performance of grass fed calves. In an experiment with Ayrshire calves which were weaned at 3 weeks of age, Preston found that a concentrate mixture which contained 10% dry skim milk powder was more palatable and produced significantly greater liveweight gains than the same ration in which the dry skim milk powder was replaced with linseed cake meal. A greater response in liveweight gain was also found in older Friesian calves (14-30 weeks of age) fed dry skim milk as the supplement compared with common soya bean concentrate (Keane and Harte, 1982). Again dry skim milk accounted for only 24% of total DM intake. How the high amount of dry milk powder in the ration decreased liveweight gain is not clear. It seems that frequent health complaints (see Table 3.18) and the lower herbage intake (see Table 3.4) of P calves may be the important factors which accounted for the lower liveweight gain. The lower liveweight gain of P calves did not only occured during period II but also induced a carry over effect into period III (see Table 3.14).

Supplement any milk in liquid form (L) was found to induce a higher liveweight gain than that from dry milk (P) (see Table 3.14). There have been no other experiments carried out to compare these two forms of milk supplement in young calves (5-10 weeks of age). However, in older calves (14-30 weeks of age), Keane and Harte (1982) found only a small and non-significant difference in liveweight gain between milk supplemented in the dry and liquid forms (896 and 959 g/d

respectively). Similarly, in an experiment comparing fish meal in dry and liquid slurry as the protein supplement to weaned Friesian calves during 4-24 weeks of age, Bush and Nicholson (1986) found no difference in liveweight gain between treatments. This indicates that the advantages of having liquid supplement by-pass the rumen may be lower than would be expected. Reliable closure of the oesophageal groove (by the teat suckling) would certainly have been expected in the present experiment because of the young age of the calves (Hegland et al 1957). So there may have been a difference in the site of digestion of milk in the two milk treatments which could account for the difference weight gains obtained. In older calves (14-30 weeks of age) more liquid milk may reached the rumen,or alternatively much of the dried milk may have reach the abomasum,(because of its small particle size) which would have accounted for the different results obtained by Keane and Harte (1982) and in the present experiment.

It may be concluded that when feeding a milk supplement to calves, there would only be an advantage in feeding in the liquid form,rather than in the dry form,when milk is fed to young calves less than 10 weeks of age and provided artificial teats are used.

The average CP intakes of calves in the current experiment were relatively high compared to their requirements (see Table 3.7 and section 1.3.2.3). Calves of 60-80 kg liveweight require 191-198 gCP/calf (for the liveweight gain 0.5 kg/d ,assuming protein digestibility is 0.81;Roy,1980). The CP content of the ration in S,P,L and G groups were 28, 26,28 and 29% respectively (calculated from data in Table 3.4 and 3.7). Reid (1986) and Beever (1978) found that the N content of autumn pasture was higher than that of spring pasture and that much of the extra nitrogen over that required had been lost from the rumen (MacRae et al,1985). However it is still suggested that the CP in the ration of all treatment groups in the current experiment were in excess of requirements and energy rather than CP intake that limited liveweight gain of calves

Although the S supplemented calves had a significantly higher daily herbage DM intake (g/calf) (see Table 3.4) and higher ME intake (MJ/calf) (see Table 3.7) than calves with P supplement their liveweight gains were not significantly different (see Table 3.14). This implies that liveweight gains were influenced by other factors apart from ME intake.For example,liveweight gains of calves had a significant positive relationship with the ratio of their ME to CP intake (KJ ME/g CP, see section 3.5.1). The L treatment provided the higher ME:CP ratios and the G treatment was the lowest. This ratio may be important nutritionally and a higher ratio of ME to CP intake would be associated with an increase in liveweight gain. This finding was supported by the conclusion of Davey (1974) that milk and milk substitutes fed to calves contained a surplus of protein to the animal's requirement and that energy rather than protein is generally limiting. Similarly, in an experiment where calves were fed a complete diet, Preston et al (1965) found that calves fed on a diet with 21.75% CP, energy rather than protein limited further nitrogen retention compared to those fed a diet with 14.8-19.4% CP.

It can be concluded that liveweight gain of calves fed with supplement food of a high value of ME per unit CP might be the best supplement to feed along with a herbage diet which already contains a high level of CP.

4.2.2 Post supplemental period

The clear superiority of liveweight gain of animal fed supplements during period II (5-10 weeks of age), was mainly lost in the subsequent period (period III,10-33 weeks of age, see Table 3.14). These results are agreement with those of Donnelly (1977); Gleeson (1971);and Lonsdale and Taylor (1969). During the post supplemental period when all calves were grazing pasture as one mob, growth rates were negatively related to increasing meal allowance in the previous treatment period (Donnelly,1977). It was found that immediately after the calves were weaned from milk or concentrate supplement onto an all-grass diet, their intake of grass dry matter increased

(Gleeson, 1971). However, intake of herbage after weaning onto grass is often related to their previous herbage DM intake. Thus positive relationships were found between the herbage DM intake prior to weaning and after weaning by Le Du et al (1976); Wang et al (1985); Hodgson (1971e). In the current experiment, liveweight gains during period III were positively related to total DM intake and herbage DM intake during Period II. There was no relationship with supplement DM intake but gains in Period III were negatively related to herbage substitution rate during period II (see section 3.5.2).

It may be concluded that liveweight gains after the supplemental period were partly due to the development of total DM intake and herbage DM intake during supplemental period (Period II). Among the supplemented calves, the S supplement calves consumed the highest total DM intake and herbage DM intake.

The liveweight gains during period III had no relationship with those during supplemental period (period II) or the final liveweight resulting from supplementation.

The mean liveweight advantage of calves resulting from supplementation (S,P,L) over those fed pasture only at the end of period II (10 weeks of age), and at the end of Period III(33 weeks of age) are shown in Table 4.2.

Table 4.2 Liveweight difference between supplemented calves and control calves (G)

group	10 weeks of age (Kg)		33 weeks of age (Kg)	
	mean	difference	mean	difference
S	82.4	7.8	231.4	14.3
P	79.9	5.3	212.5	- 4.6
L	86.7	12.1	228.8	11.7
G	74.6	0.0	217.1	0.0

These results are in general agreement with those of Byford (1973); Harte et al (1984); and Reardon and Everett (1972) as shown in Table 4.3.

Table 4.3 The carry over effect on liveweight of young calves

Feed comparison	age (weeks)	liveweight difference at (weeks)	Kg	at (months)	Kg	breed,sex
(1) concentrate and grass	5-8	12	14.8	8	15	Friesian,bull
(2) high and low milk	up to 8	12	13	10	13	Friesian,bull
(3) high and low milk+ concentrate	birth to 12	12	20	21	29	Jersey and Friesian x Jersey bull

(1) Byford (1973), (2) Harte et al (1984), (3) Reardon and Everett (1972)

The difference in liveweight established in the experiment with the soya concentrate supplement tended to increase subsequently while that for liquid milk was maintained. It seems that the concentrate supplements had a positive effect on subsequent liveweight gain and hence the higher final liveweight. On the other hand, milk powder supplement (P) had a negative effect on subsequent liveweight gain and hence the lower final liveweight compared to the control group (G). The development of the herbage DM intake after the supplemental period may be an important factor which determined liveweight gain (as discussed in the previous section) and hence the liveweight of grazing calves in this experiment. However, it must also be observed that the difference between the liveweights of supplemented calves

(S,P,L) at 33 weeks of age were not statistically different from G calves (see Table 3.10). Further investigation should be carried out to measure the extent to which supplements may influence the herbage DM development,after the supplemental period,of calves grazing pasture.

4.3 HEALTH

Scours occured in all treatments particularly during the first week of period II (see Table 3.18 and Figure 3.6). Poor adaptation of the reticulorumen at the time that feed is changing from milk to solid feed, may cause the occurence of scours in the first week after weaning. However, scours occurred less frequently in the P calves than the other groups (see Table 3.18). In contrast, Keane and Harte (1982) found one calf on milk powder supplement scoured persistently. A number of unexplained complaints occurred in calves with P supplement. Feeding milk in dry form may cause the substantial fermentation in rumen since milk has a high energy and high protein content. In addition, milk in dry form appeared hard to ingest and probably led to excessive weight loss in one calf. Calves in the non-supplemented group (G) were severely affected by weaning "stress" due to the low consumption of grass and this led to the death of one calf. This severe stress in early weaned calves on pasture also occurred in the work by Gleeson (1971).

4.4 FEED EFFICIENCY

From Table 3.20 the actual liveweight gains are lower than the estimated value in calves with S and G treatments whereas the actual liveweight in calves with milk supplement were similar (P) or higher (L) than the estimated value. Although P and L calves were fed the same ration, the liveweight gains were different. It is probable in the L supplement group that milk was rumen by-passed and therefore losses in the form of methane gas (result from fermentation in rumen) was less than those with P supplement. Therefore the metabolisibility of DE for calves with L supplement should be

higher than the assumed value (0.82; see section 2.33). This conversion factor was found to be 0.94 for calves fed milk and concentrate in an experiment by Hughes et al (1977).

The actual mean liveweight gain of S and G calves were lower than their estimated values. This was probably because the efficiency of utilization of ME for maintainance (K_m) and for growth (K_g) were lower than those for milk supplement (P and L calves). L and P supplement have higher metabolisibility than S supplement and herbage (G) (see Table 3.1 and 3.3). The higher the metabolisibility (q)of feed , the higher the efficiency of utilization of ME,both for maintainance (K_m) and for growth (K_g) (A.R.C., 1980).

The daily ME requirement for maintainance estimated from the daily ME intakes and liveweight gains of calves fed milk supplement (P and L) in this experiment were 9.57 MJ ME/calf or 0.39 and 0.37 MJ ME/$Kg^{0.75}$ per day for P and L calves respectively. It is similar to those calves fed fresh milk in the experiment of Holmes and Davey (1976) (0.38 MJ ME/$Kg^{0.75}$per day) and to the value of Hughes et al (1977) of 0.41 MJ ME/$Kg^{0.75}$. The estimation of ME requirement for maintainance of calves in S and G treatments could not be made due to the high variation within treatments. The value for S and G calves were therefore assumed to be the same as for the P and L calves.

The ME requirement for growth of P and L calves were estimated from the one equation while those for S and G calves were estimated from the mean values of ME intake and liveweight gain in each treatment. The ME requirement per 1 Kg liveweight gain for S, P, L and G calves were 26.8, 14.0, 14.0 and 48.9 MJ respectively (see section 3.5.3). The estimated value for ME requirement per 1 Kg liveweight gain for supplement with milk (P and L) were similar to calves fed milk and concentrate in experiment by Hughes et al (1977) of 14.89 MJ and those with milk and solid feed in experiment by Holmes and Davey (1976) of 13.6 MJ. The estimated values for S and G calves are higher than those fed supplement with milk (P and L). It is likely that the K_m and K_g values for S and G diets were much lower

than those for the P and L diets; and that (see Table 3.1 and 3.3) for grass fed calves lower than that for the soya bean concentrate diet.

It should be concluded that the nature of the supplement fed may strongly influence metabolisibility of the total ration and hence the efficiency with which ME is utilized for growth of young calves grazing autumn pasture. In this experiment, the supplement with milk (P and L calves) probables had a higher efficiency of ME utilize for liveweight gain than S and G; and the non- supplemented (G calves) were the lowest. Further work is required to fully account for the large differences in the responses obtained from the calves fed the different supplements.

4.5 THE USE OF MARKERS

In this experiment two markers were used to estimate the food intake of treatment calves. These were Polyethylene glycol (PEG) and Chromium oxide. PEG was mixed into the concentrate mix (S,P,and L) and the amount of PEG presented in the faeces was used to estimate the concentrate DM intake. The PEG concentration of composite faecal samples over 4-5 day periods were used to overcome the large diurnal variation in excretion rate which may occur (Corbett et al,1958). The reported low recovery rate of PEG in faeces possibly due to artifacts arising during analyses of faeces (Corbett et al,1958),was avoided in the current experiment because the concentrate DM intake by individual calves were estimated from the relative amount of PEG in faeces and by apportioning the measured disappearance of concentrate (within treatment and paddocks) on the basis of their total excretion of PEG. It was therefore found that the estimated mean of supplement DM intake for S,P and L calves were very similar to the mean amount offered (see Table 3.2 and 3.4) and supplement DM intake increased as expected with time (Fig. 3.1)

Chromic oxide in controlled release devices (CRD) were used to estimate total faecal output of individual calves

within treatments and paddocks. The rate of Chromic oxide excretion and estimated digestibilities of ration consumed were adapted from the indoor experiment by Kassano (1987). The mean estimates of total DM intake and herbage DM intake per kg LW (Table 3.4) were similar to those measured by Hodgson et al,(1971) in the field and by Kassano (1987) indoors. Although the measurement period of food intake was only 25 days (6-30 day of Period II), the estimated values seemed to largely account for the observed differences between the growth rates of the treatment groups. There is no other way of assessing the accuracy of the methods used without doing indoor experiments.

It can be concluded that the use of Chromic oxide and PEG as markers to estimate food intake of calves has potential.

CHAPTER 5

FINAL DISCUSSION AND CONCLUSION

The results of this study contribute towards our understanding of calf rearing in general and in particular go some way towards answering the particular practical questions posed in the introduction.

It is quite clear that calves that received large quantities of milk up until 5 weeks of age can not be safely weaned immediately on to pasture, even if they are 65-70 kg in liveweight. One calf was lost and many had their growth rates checked in this experiment because the transition to solid feed was too rapid. The calves in this experiment which were weaned onto autumn pasture over several days took many weeks to recover to satisfactory growth rates (500 g/d).

Although no direct comparison was made, the absolute growth rates obtained from the autumn pasture suggested that it had a lower feeding value than spring pasture,inspite of being highly digestible.

The feeding of all supplements increased the liveweight gain of the calves. Liquid milk produced the highest response and showed that restricted levels of milk feeding may offer a practical means of inducing calves to eat more solid feed, while preserving growth rates. However, soya bean concentrates also maintained moderate to high liveweight gains and did not appear to depress herbage intake to the extent to which the liquid milk did . The efficiency of use of energy (or protein) from the milk containing diet was therefore clearly higher than the soya bean concentrate diet . The reason for this requires further work, but may be related to the site of digestion (milk in abomasum) or feed quality. The ratio of ME to CP in the diet was higher for the calves given milk and this may have led to the more efficient gains.

The final (33 week) liveweight of calves on these two treatments were similar which is perhaps the most important point of practical significance. The relative costs of those supplements and the amounts of labour required to feed them should determine their relative use in practical calf rearing systems.

The use of milk powder as a major component of a dry concentrate feed could not be considered as a practical alternative for an early weaning supplement. This was on account of the many and varied health problems which occured within this treatment group and inspite of a higher growth rate obtained compared with the unsupplemented controls. It would seem likely that the digestion of milk powder in the rumen may have interfered with the digestion of herbage as the substitution rate was highest in this treatment.

The slow release devices used for releasing Chromium provided satisfactory estimates of faecal output although loss of units from calves over 70 kg liveweight was a problem which will limit their use to young calves. Intake estimates were very dependent on the digestibility values assumed and it is recommended that parallel indoor experiments be conducted using the same feeds whereever possible.

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APPENDIX

Table 1 Analysis of Variance of initial liveweight

Source of variation	DF	SS	MS	F value	Significance of F
Tr	3	18.02	6.01	0.49	NS (0.692)
Blk	3	21.08	7.03	0.57	NS (0.638)
Error	25	306.95	12.28		
Total	31	346.06	149.17		

Table 2 Analysis of Variance of final liveweight of Period II

Source of variation	DF	SS	MS	F value	Significance of F
Blk	3	65.45	21.82	0.61	NS (0.618)
Tr	3	606.99	202.33	15.18	* (0.026)
Sex	1	71.76	71.76	5.38	NS (0.103)
Tr x Sex	3	39.99	13.33	0.37	NS (0.775)
Error	20	718.22	35.91		
Total	30	1502.40			

Table 3 Analysis of Variance of liveweight gain during Period II

Source of variation	DF	SS	MS	F value	Significance of F
Tr	3	643031.67	214343.88	12.80	***(0.00001)
Blk	3	12578.04	4192.68	0.25	NS (0.8603)
Error	24	401895.17	16745.63		
Total	30				

Table 4 Analysis of Variance of liveweight gain during Period III

Source of variation	DF	SS	MS	F value	Significance of F
Tr	3	28027.27	9342.42	1.22	NS (0.32)
Blk	3	19102.17	6367.39	0.83	NS (0.49)
Error	24	183864.83	7661.03		
Total	30	230994.27			

Table 5 Analysis of Variance of herbage DM intake during Period II

Source of variation	DF	SS	MS	F value	Significance of F
Tr	3	2272762.92	757587.63	18.67	***(0.00001)
Blk	3	130684.63	43561.54	1.07	NS (0.3883)
Error	16	649353.58	40584.60		
Total	22				

Table 6 Analysis of Variance of total DM intake during Period II

Source of variation	DF	SS	MS	F value	Significance of F
Tr	3	976685.05	325561.68	6.76	** (0.004)
Blk	3	835.98	278.66	0.01	NS (0.999)
Error	16	770479.49	48154.97		
Total	22	1748000.52			