End of Project Report

FEEDING TECHNIQUES TO INCREASE CALF GROWTH IN THE FIRST TWO MONTHS OF LIFE

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Contents

1. SUMMARY

Data from Cornell University and the University of Illinois in the USA suggested that average daily liveweight gains of 900 to 1000 g/calf/day could be achieved from birth to weaning provided the calf milk replacer (CMR) is formulated to meet the calf's amino acid requirements for such a rate of gain. Their findings suggested a daily milk replacer DM allowance of 1250 to 1500 g/d with a crude protein content of 26 to 30%. A series of studies were undertaken, at ARINI with home born dairy calves and at Grange Beef Research Centre with purchased dairy calves, to determine the effect of increasing the daily milk replacer DM allowance and or increasing the crude protein content of the CMR on calf performance. The main outcomes of these studies were

- There was no growth or intake response in any of the studies to increasing the crude protein content of the CMP from 23% to 28%.
- Calf growth rates responded to increasing the daily milk replacer allowance from 600 to 1200 g/day for both home bred and purchased calves. However, the effect was not significant post-weaning in any of the studies.
- In all of the studies (for both home reared and purchased calves) feeding a high level of CMR decreased concentrate DM intake. However, the calves concentrate intakes were similar post-weaning.
- The home bred calves with free access to the milk replacer feeders failed to consume their 1200 g/day allowance. Calves offered 600 or 1200 g of CMR/day had average consumption of 554 and 944 g/d, respectively, in the milk feeding period.
- Feeding a high (1200 g/d) compared to a low level (600 g/d) CMR diet for the first 56 days had no significant effect on carcass weight or carcass characteristics when purchased male calves were slaughtered off an *ad libitum* concentrate diet after 388 days. The final carcass weights were 231 and 240 kg for the respective 600 and 1200 g/d CMR.
- Reducing the fat content of the CMR from 18% to 12% did not have any effect on concentrate intake or liveweight gain.

2. INTRODUCTION

Data from Cornell University and the University of Illinois in the USA indicate that average daily gains of 900 to 1000 g/d can be achieved from birth to weaning at 8 weeks of age provided that the milk replacer is formulated to meet the calf's amino acids requirement for such a rate of gain. Findings from these institutions indicate that a calf milk replacer with 26 to 30% crude protein is required to support these high rates of liveweight gain, and in addition, the high protein diet leads to increased lean tissue growth and reduced fat deposition. The implication of these findings is that calf liveweight gain and lean tissue deposition in our normal calf feeding programmes may be retarded due to limited protein intake.

For more than 30 years recommendations relating to restricted feeding of calf milk replacers indicated that 20 to 23% crude protein was adequate to meet the calf's protein requirements. The daily milk replacer dry matter (DM) allowance was 450 to 750 g/d at 10 to 12.5% DM concentration and was fed in association with an *ad libitum* concentrate-based feed to achieve a liveweight gain of 450 to 600 g/d in the period 7 to 56 days. The new accelerated lean growth system proposed by Cornell and Illinois requires a daily milk replacer DM allowance of 1250 to 1500 g/d at a 15 to 18% dry matter concentration. Many of the trade magazines proclaimed the merits and benefits of the new US system which is in sharp contrast to the current calf rearing system which Teagasc had been promoting as appropriate for dairy calves. A series of experiments were conducted to address calf rearing issues which collectively involve feeding milk replacer with higher crude protein level, higher DM concentration.

2.1 Scientific Rationale

In the latter third of the last century the incentive was to wean dairy calves at 5 to 8 weeks of age off relatively expensive whole milk or milk replacer and onto less expensive concentrate-based feeds. This practice was facilitated by feeding a fixed level of milk replacer (500 g powder/calf day) from 7 days to weaning at 6 to 7 weeks of age and allowing the calf *ad libitum* access to concentrate feed and water (Fallon 1992).

In the 80's, most calf milk replacers were based on a minimum of 60% skim milk powder and had a minimum crude protein declaration of 23%. In the 90's, milk replacer had a reduced dependency on skim and there was a downward trend in the crude protein content such that currently 20 or 21% crude protein declaration is the norm. The expected calf liveweight gain from the 500 g/day milk powder plus concentrate-based ration offered *ad libitum* is in the order of 450 to 600 g/day in the period to 42 days (Fallon 1992). Recently, scientists, from Cornell University (Van Amburgh *et al.*, 2001) asked the question "is the practice of restricting liquid feed intake the most biologically sound approach to achieving optimum calf growth and health". They added that "we know of no other neonatal system that is successful at enhancing future productivity by restricting milk intake in an effort to force weaning, humans included". In the US, the current focus is on "accelerated growth rate for calves which involves feeding 900 to 1200 g of powder per calf/day which is approximately twice that of the conventional recommendation of 450 to 570 g powder/calf/day (Drackley 2002). The milk replacer is formulated with a higher crude protein content (26 to 28%) to meet the needs of the rapidly growing muscle for protein (Van Amburgh et al 2001). The aim of the "accelerated growth" programme is to capatalise on the rapid early lean growth potential of young calves and allow for greater lean growth without fattening (Drackley 2002). Under this system the target growth rate of 900 to 1000g/day is expected in the period 7 to 42 days of age. At Cornell University using a 30% crude protein milk replacer formulation they achieved a high rate of lean tissue deposition without fattening (Diaz et al 1998, 2001). At the Univeristy of Illinois they found that body fat content was decreased as protein content increased in milk replacer of constant energy content (Bartlett *et al.,* 2001; Blone *et al.,* 2003). This agreed with the previous findings (Donnelly and Hutton 1976; Gerrits *et al.,* 1996). The linear increases in lean tissue deposition with increasing dietary crude protein (Blone *et al.,* 2003) show that is possible through dietary manipulation to a produce high rate of lean growth without the fattening which occurs in veal production.

Drackley (2002) stated that there is little data available to draw conclusions about the impact of nutrition during the first 60 days of life on subsequent productively and longevity of cows. However, he indicated that at least three major areas might be affected

1. health and immune status
2. development of milk production potential
3. metabolic imprinting

Bork *et al* (2000) reported that calves fed on an accelerated growth programme had a greater concentration of circulating IGF-1 than calves fed milk replacer at a conventional (restricted) rate. This clearly indicates a functional IGF-1 system in the young calf which is responsive to early nutritional status. Van Amburgh *et al* (2001) indicated that traditional feeding strategies do not allow full expression of the somatotropic axis as indicated by increased serum IGF-1 concentrations.

Higher nutrient intake during early life is likely to improve immune status. Nonneche *et al* (2000) demonstrated that feeding for greater growth rate resulted in increased nitric oxide and gamma interferon production from isolated mononuclear leukocytes compared with cells from conventionally fed calves. Pollock *et al* (1993) found that calves at a higher plane of nutrition (1000 v 400 g/d of powder) had improved responses of cell mediated immunity and decreased skim response to antigens. Similarly calves which were fed below maintenance had a decrease in lymphocyte proliferation response compared to calves which were adequately fed (Griebel *et al*., 1987).

A high plane of nutrition in early life may have a long term positive effect on mammary development. Brown et al (2002) reported that a growth rate of 670 g/d (H) in the period 2 to 8 weeks followed by 440 g/d (L) in the period 9 to 14 weeks produced 79 mg of parenchymol DNA/100 kg BW at 14 week. The corresponding value for liveweight of 670 g/d (H) followed by a liveweight of 1100 g/d (H) was 86 g, in contrast, low gains of 380 g/d (L) followed by high gains of 1100 g/d (H) was 42 g and low gains of 380 g/d (L) followed by low gains of 440 g/d (L) was 45g. This finding clearly indicates the importance of a high plane of nutrition in the first 2 month of the calf's life to enhance mammary development. An Israeli study (Bar-Peled *et al.,* 1997) found that calves which were on a high plane of nutrition for the first 6 weeks of life calved 30 days earlier and produced 450 kg more milk in their first lactation compared to calves fed on a conventional amount of calf milk replacer.

Drackley and Bartlett (2002) stated that another area that remains to be investigated in calves is the concept of nutritional "imprinting" during early life on subsequent metabolism and productivity. Effects of neonatal nutrition on later life responses are well documented in other species (e.g. Holemans *et al.,* 1996; Desai and Hales, 1997) but have been little investigated in cattle. Growth and responsiveness to various hormones in adult life may be altered by nutritional status during the neonatal period.

Drackley and Bartlett (2002) concluded that a better understanding of both the short- and long-term impacts of nutrition during the first 60 d of life is needed to optimise lifetime productivity.

In order to achieve liveweight gain of 900 to 1000 g/d in the first 2 months of life it is necessary to achieve daily dry matter intake of 1200 to 1500 g. Roy (1980) reported maximum DM intakes of 2.75, 2.50 and 2.25 % of bodyweight for liveweights of 40, 60 and 80 kg, respectively, so it is evident that a 60 kg calf has the capacity to consume 1500 g of powder per day. The ideal DM concentration of the milk replacer diet to achieve high DM intakes is not clear. Data from Grange (Fallon 1992) and Illinois (Drackley and Bartlett 2002) would indicate 12.5%, while data from Cornell (Van Amburgh *et al.,* 2001) would indicate a 15% for the first 2 weeks, increasing to 18%, thereafter. The French system (Sissions, 2002) uses a 20% DM diet from 2 week of age.

It is possible that the DM concentration of the milk replacer which is offered may be linked to the nutrient composition of the milk replacer. Historically 12.5% DM was selected as it was similar to that of cow's milk. Higher DM concentrations were considered to increase the risk of digestive upsets if the calves did not consume additional water.

2.2 Proposed Benefits

The optimisation of lean tissues growth through accelerated growth rate in the young calf in the first 2 months of life offers the following benefits:

1. Increased growth rate during the most efficient period of calf's life (first 2 months of life) and the prospect of improved subsequent lifetime performance.
2. Decreased cost of gain due to greater feed efficiency and an overall reduction in labour input.
3. Increased lean body gain.
4. Heifers for dairy herd replacement will be heavier at breeding time.

In addition, the component research with respect to the crude protein and the DM concentration of the milk replacer diet will provide important nutritional landmarks which can be used to optimise calf feeding systems. It is expected that an optimum system for accelerated growth will improve the lifetime health and welfare. The impact of accelerated calf growth on the environment and rural development is speculative as the response to longevity and health is unknown but if positive would reduce the number of replacement heifers required. The serum concentration of IGF-1 may provide a practical marker in respect to the calf's nutritional status as expressed through the somatotropic axis.

2.3 Rumen Development

Early rumen development can be influenced by a number of nutritional factors such as high milk replacer intake or high energy density of the CMR which will result in low starter intake and this may in turn delay rumen development. There is an energy and protein cost of the increase in the mass of the ruminal gastrointestinal tract during rumen development. This can be optimised with the correct level of dry matter intake from the liquid diet with rumen development arising from solid food intake. Short chain fatty acids such as butyric and propionic (produced from the fermentation of sugars and cereal grain) promote normal papillary development in the rumen. Therefore there is a necessity to have complementary ingredient composition of the liquid and solid diets. The success of the approach is dependent on a healthy gut which can be enhanced through the addition of “essential oils” to the diet. Greenline and Eimericox are products which contain etheric oils, specific fatty acids, sugars and methyl donors which are know to have a positive effect on coccidian, FCR, fat deposition and growth rates in lambs. We need to explore the possibility that these effects may also be seen in claves.

Feeding the calf with a milk replacer, that is rapidly absorbed post feeding, should be of a type and level which encourages earlier starter intake to hasten development of the rumen. The aim being to stimulate the urge to consume solid food within 12 hrs of feeding the milk diet. Feeding a milk replacer of lower energy density and at a level which will not increase the risk of digestive upsets should encourage solid food intake.

3. Material and Methods

In 2003 a collaborative research programme involving both the Agri-Food and Biosciences Institute (AFBI) Hillsborough and Grange Research Centre was initiated to study the effects of increasing milk replacer intake and milk replacer crude protein content on the performance of replacement dairy heifers and beef calves.

3.1 Study 1.

One hundred and fifty three Holstein-Friesian (88 heifers, 65 bulls) calves were allocated to one of four treatments at 5 days old, based on birth weight, genetic merit of dam, sire, and sex. The average birth weight of the calves was 43.8 (s.d. 0.4) kg.

A 2 X 2 factorial design was used involving two levels of CMR feeding: 5 or 10 l/day (120 g of CMR powder per litre of water); and two milk replacers containing either 230 g CP/kg dry matter (DM)) or 300 g CP/kg DM . Calves were introduced to CMR treatments on day 5 and remained on these treatments until day 56.

From day 5 until weaning at 56 days, CMR was fed via automatic teat (Forster Technic) feeders. Milk replacer allowance was reduced in equal steps from day 49 to weaning at day 56 for the 5 l/day treatments, and from day 46 to 56 for the 10 l/day treatments. The CMRs were whey-based, containing mainly milk-derived protein. Calf health was continually monitored throughout the study with duration of illness and days of treatment recorded.

Calf starter concentrate was offered *ad libitum* from day 5 via feeding troughs placed at the front of the group pens. Post-weaning, calves were moved out of the milk feeding pens and housed in groups (n ≤ 25) bedded on straw up to 12 weeks of age. During this period from weaning (day 56) up to 12 weeks old, calves were offered 2 kg concentrate/head/day, and *ad libitum* grass silage. At 12 weeks heifer calves were moved into the cubicle accommodation. Performance post weaning was recorded in the female animals only. Heifer calves in cubicle accommodation were housed in groups of 14, with at least 1 cubicle per calf. Calves were offered *ad libitum* grass silage and 2 kg of heifer concentrate/head/day. Silage and concentrate intakes were recorded on 5 days per week from 12 weeks up to turn out. During this period average intake of silage was 1.34 kg DM/day (s.d. 0.112). Calves were turned out to grass during April and May and re-housed in cubicle accommodation during October.

Heifers were offered grass silage *ad libitum* and concentrates (2 kg/head per day) from October until turnout the following April..

Individual CMR intakes were recorded on 5 days per week from day 5 until weaning at day 56. Daily CMR intake was recorded from the automatic feeder computer programme (Kalbman, supplied by Forster Technic). Group intakes of calf starter concentrate were recorded by measuring the amount of concentrate offered per week minus the refusals.

Live weight was recorded at weekly intervals and skeletal size was recorded fortnightly throughout the pre-weaning phase of the study. Skeletal size was estimated from linear measurements including height at withers, length from shoulder to hip and heart girth (Hoffman, 1997). Post-weaning live weight, skeletal size and body condition were recorded at monthly intervals in both studies.

3.2 Study 2.

Sixty-four 2 to 3 week-old Holstein/Friesian calves with an initial weight of 50 kg (+/- 1.8 kg) were allocated immediately following purchase to the following treatments: (1) 23% crude protein CMR at 600 g/d (LL), (2) 23% crude protein CMR at 1200 g/d (LH), (3) 30% crude protein CMR at 600 g/d (HL) and (4) 30% crude protein CMR at 1200 g/d (HH). The milk replacer was offered warm by bucket with the daily allowance reduced to encourage solid food intake in the period 42 to 56 days. All calves had *ad libitum* access to a concentrate diet throughout the 16-week experimental period. In the initial 56-day period all calves were individually penned on straw with a pen area of 1.5 m^2 per calf. Thereafter, groups were penned according to treatment on concrete slats.

3.3 Study 3.

Thirty-six 2 week old Holstein/Friesian calves with an initial weight of 45 kg (+/- 1.6 kg) were allocated on purchase to the following treatments: (1) 23% crude protein CMR at 750 g/d (LM) and (2) 30% crude protein CMR at 1200 g/d (HM). Feeding and management of the animals was similar to Experiment 1 for the first 112 days of the experiment. Thereafter, all calves had *ad libitum* access to a 16% crude protein concentrate ration. The calves were accommodated according to treatment in four pen on concrete slats. Grass silage was offered daily as a roughage source (approximately 10% of total dry matter intake). The animals were slaughtered after 388 days on experiment.

3.4 Study 4.

Eighty Friesian x Holstein male calves purchased from local farms at 7 to 14 days of age, and on arrival were allocated to the following (2 x 2 x 2 factorial) arrangement of treatments

1. 18% fat CMR std + std ration
2. 12% fat CMR std + std ration
3. 18% fat CMR std + Greenline ration
4. 12% fat CMR std + Greenline ration
5. 18% fat CMR Eimericox + std ration
6. 12% fat CMR Eimericox + std ration
7. 18% fat CMR Eimericox + Greenline ration
8. 12% fat CMR Eimericox + Greenline ration

The milk replacer was reconstituted at the rate of 180 g/l of water (38°C) and fed once daily, by bucket, using the following programme starting with 7 to 14 day old purchased calves.

Period days	Amount (g/d)	Volume (l/feed)
1 – 4	540	3
5 – 28	720	4
29 – 35	540	3
36 – 42	360	2

Eimericox was included in calf milk replacer at a rate of 6 g/kg of day powder, for treatment 5 through 8 and Greenline was included in the concentrate ration at a rate of 4g/kg of ration.

All animals were weighed on day 1 of the study and at 14 day intervals thereafter, milk replacer and concentrate intakes were recorded daily. Diarrhoea and respiratory disease categories as Normal (0), Mild (1), Moderate (2) or Severe (3).

4. Statistical Analysis

In study 1 the data were analysed using repeated measures analysis of variance and regression analysis, fitting fixed effects for treatment, sex, age and their interactions. Statistical analysis was carried out in two parts for the period from birth to weaning (day 56) and then for the period from weaning onwards. Statistical analysis was carried out using Genstat 6 (Lawes Agricultural Trust, 2002).

In study 2 the data was subjected to a two-way analysis of variance. In study 3 data was subjected to analysis of variance. In study 4 the data for liveweight gain and feed intake was analysed using three way Analyses of Variance and the "t" test was be used for comparisons of treatments. Where appropriate the effect of treatment on the incidence of diarrhea, respiratory disease and mortality was examined by Chi-square analyses (Snedecor 1986).

5. RESULTS

5.1 Automatically fed calves – study 1

Milk Replacer Intake: There was a significant difference in CMR intake between calves offered 5 l/day and those offered 10 l/day (Table 1). Calves offered 5 l/day consistently drank their whole allocation of CMR whereas milk replacer intake for calves offered 10 l/day increased from 6.2 in week 1 to 9.1 l/day in week 4. From week 4 to 7 CMR intake for calves offered 10 l CMR/day remained relatively constant. Calves offered 5 and 10 l CMR/day consumed on average 554 and 944 g CMR/day (s.e.d. 15.3).

Concentrate Intake (pre-weaning): Calves offered 5 l/day consumed on average 0.43 kg concentrate DM/day, while calves offered 10 l/day consumed only 0.28 kg concentrate DM/day (s.e. 0.015). There was no difference in the concentrate intake of calves offered either the 230g CP/kg DM or 300g CP/kg DM milk replacers and no interaction between CP content and milk feeding level.

Table 1. Live weight (kg) and live weight gains (kg/day) for Holstein-Friesian calves offered 5 versus 10 litres milk replacer per day and either a milk powder containing 230 or 300 g CP per kg powder[1]

	Milk replacer offered (l/day)				Milk replacer CP content[2]			
Age (days)	5	10	SED	SIG	230 g/kg DM	300 g/kg DM	SED	SIG
Live weight (kg)								
Day 28	49.3	55.8	0.72	***	52.7	52.3	0.71	NS
Day 56	62.7	71.6	1.12	***	68.2	66.1	1.11	NS
Day 90	92.0	96.5	2.05	*	95.2	93.4	2.03	NS
Day 270	238	237	6.76	NS	241	234	6.73	NS
Day 630	500	498	8.02	NS	503	494	7.94	NS
Live weight gain (kg/day)								
0-28	0.21	0.44	0.026	***	0.33	0.31	0.025	NS
28-56	0.48	0.57	0.026	**	0.55	0.49	0.026	*
0-56	0.34	0.50	0.020	***	0.44	0.40	0.020	NS
56-180	0.75	0.74	0.032	NS	0.74	0.75	0.031	NS
180-270	0.96	0.89	0.066	NS	0.93	0.92	0.066	NS
360-540	0.78	0.78	0.031	NS	0.79	0.77	0.031	NS
540-720	0.86	0.85	0.046	NS	0.83	0.89	0.045	NS

[1]There were no significant feeding level by CP content of the CMR interactions ($P > 0.05$).
[2]** $P < 0.01$; *** $P < 0.001$. Bull calves removed from study at day 56.

Live weight and live weight gain: There was no significant interaction between level of CMR feeding and CMR CP content for live weight or live weight gain during the period from birth to weaning. At weaning, calves reared on 5 l/day and 10 l/day were 62.7 kg and 71.6 kg respectively, but no effect of milk replacer protein content was found. From weaning to 6 months, 6 to 9 months and up until calving no significant effect of CMR feed level or CMR CP concentration on DLWG was observed.

Skeletal size and body condition score: At day 56, calves offered 10 l/day were significantly taller and had greater heart girths at weaning compared with calves offered 5 l/day (Figure 1 and 2). There was no significant effect of CMR protein content on height. Calves offered 10 l/day had significantly higher body condition scores by weaning compared with those offered 5 l/day. Protein content had no effect on body condition score. There was no significant effect of CMR feeding level or CMR CP content on any linear measurements post weaning.

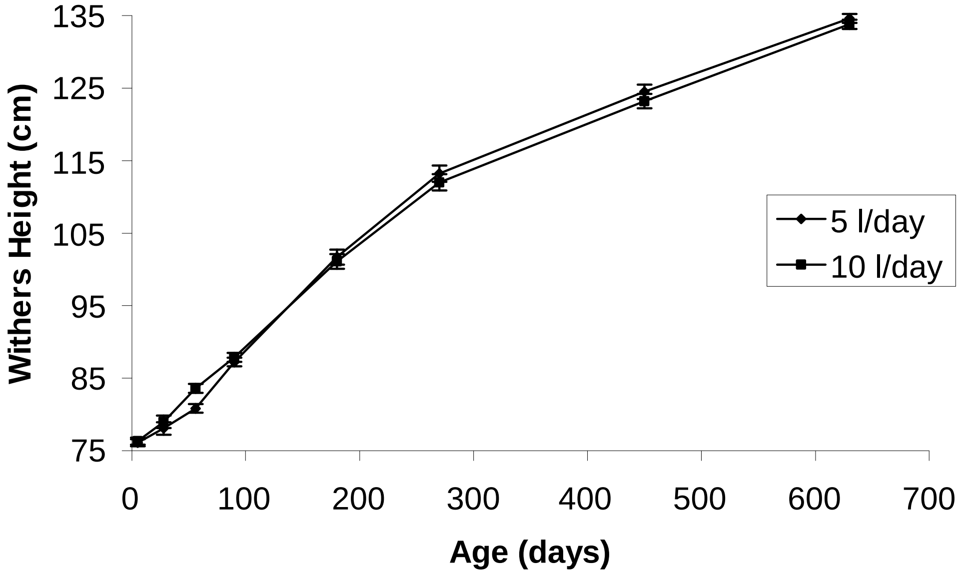

Figure 1. Temporal changes in Withers height of calves offered 5 or 10 l milk replacer per day from day 5 to 56 (S.E.D. shown for each data point)

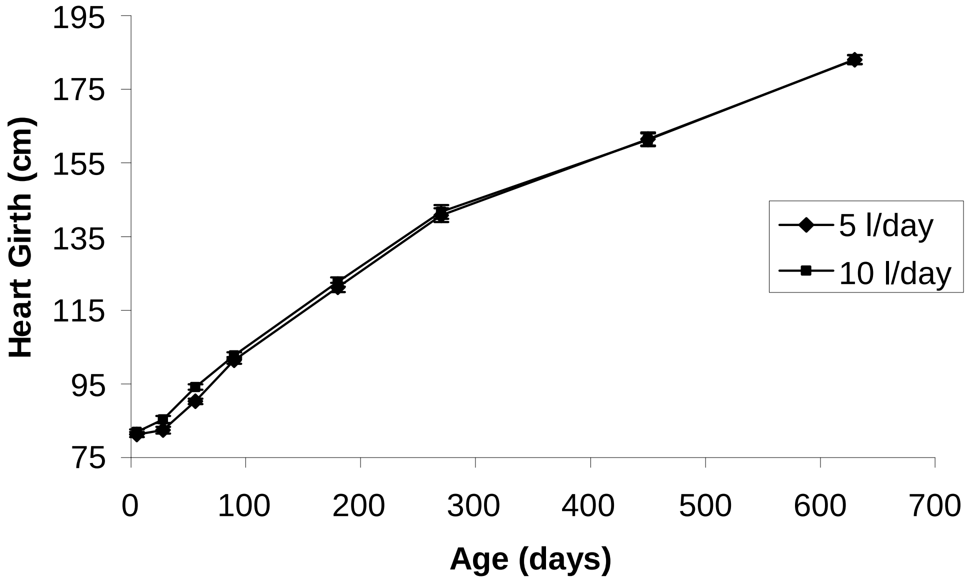

Figure 2. Temporal changes in Heart girth of calves offered 5 or 10 l milk replacer per day from day 5 to 56 (S.E.D. shown for each data point)

5.2 Study 2

The higher level of crude protein in the milk replacer (23 v 30%) did not affect feed intake or liveweight gain. In study 2, the level of feeding significantly decreased concentrate intake in the period 1 to 56 days and increased liveweight gain in the period 1 to 56 days, however, the high level of milk replacer did not significantly affect liveweight gain in the period 1 to 112 days (Table 2).

Table 2. Effect of level of feeding and level of protein in the CMR on calf performance

						Sig		
	LL	LH	HL	HH	Sem	L	P	L x P
Liveweight gain g/d								
1 - 56 days	690	760	720	870	48	*	-	-
57 - 112 days	1020	1140	1070	1110	67	-	-	-
1 - 112 days	860	950	900	990	48	-	-	-
Concentrate intake (kg/DM)								
1 - 56 days	34.0	28.2	41.1	23.2	4.12	**	-	-
57 - 112 days	180.5	189.6	168.2	211.9				
1 - 112 days	214.5	217.8	209.3	234.1				
CMR intake	30.3	57.4	29.9	56.7				
1 - 56 days (kg/DM)								

5.3 **Study 3**

The higher level of milk replacer feeding significantly reduced concentrate intake in the period 1 to 56 days but had no significant effect on liveweight gain (Table 3). After 204 days the difference in daily liveweight was 6 kg between the two treatments and after 388 the difference was 12 kg. These differences were not significant and feeding additional milk replacer with a high protein in the first 56 day did not effect carcass weight, conformation or fat score.

Table 3. Effect of CMR programme on calf performance

	LM	HM	sem	Sig
Liveweight gain g/d				
1 - 56 days	550	640	45	-
57 - 112 days	1030	1070	85	-
1 - 112 days	790	860	55	-
1 – 204 days	1070	1100	23	
205 – 388 days	1060	1120	43	
1 – 388 days	1070	1110	33	
Final carcass (kg)	457	475	12.9	-
Cold carcass (kg)	230.5	239.7	6.65	-
Conformation	3.82	3.88	0.04	-
Fat score	2.64	2.31	0.24	-
K O%	50.4	50.4	0.01	-
Concentrate intake (kg/DM)				
1 - 56 days	29.0	17.4	2.75	**
57 - 112days	150.8	150.1		
1 - 112 days	179.8	167.5		
CMR intake 1 - 56 days (kg/DM)	29.6	46.3		

In conclusion, increasing the daily CMR allowances from 600 g to 1200 g increased LWG in the period 1 to 56 day and there was no response to increasing the level of crude protein from 23 to 30%.

5.4 Study 4

In general the health of the calves was good throughout the 112 day experiment. There were no calf deaths during the experiment. The number of occasions in which antibiotics were prescribed is presented in Table 4 for the various dietary treatments. There was no significant effect of treatment or interactions on concentrate intake for any period of the experiment (Table 5). There was no significant effect of treatment on liveweight gain for any period of the experiment. There appeared to be a significant concentrate x fat interaction in the post experimental period 57 to 112 days when all calves were on a common diet (Table 6). It is difficult to determine the importance of the finding.

Table 4. Effect of fortification of the CMR and concentrate diet and the level of fat in the CMR on calf health (number of antibiotic treatments)

	CMR				CMR+			
	Conc		Conc+		Conc		Conc+	
	Fat 18	Fat 12	Fat 18	Fat 12	Fat 18	Fat 12	Fat 18	Fat 12
No. of calves	10	10	10	10	10	10	10	10
Antibiotic treatment (No)								
0 – 1	4	5	6	6	4	2	5	7
2 – 3	6	5	2	3	5	4	5	2
4-5	0	0	1	0	0	3	0	1
>5	0	0	1	1	1	1	0	0

Table 5. Effect of fortification of the CMR and concentrate diet and the level of fat in the CMR on calf concentrate intake (Study 4)

	Treatment															
	CMR				CMR+											
	Conc		Conc+		Conc		Conc+			P[1] Values						
	Fat 18	Fat 12	Fat 18	Fat 12	Fat 18	Fat 12	Fat 18	Fat 12	s.e.	M	C	F	MxC	MxF	CxF	MxCxF
Intake (kg)																
1-28 days	10.3	11.1	13.9	12.6	13.7	14.5	13.3	13.0	2.71	-	-	-	-	-	-	-
1-42 days	27.4	31.5	34.9	33.3	36.1	39.4	35.9	32.5	5.77	-	-	-	-	-	-	-
1-56 days	61.8	70.1	74.5	71.4	74.6	79.6	74.4	67.7	7.74	-	-	-	-	-	-	-

Table 6. Effect of fortification of the CMR and concentrate diet and the level of fat in the CMR on calf liveweight gain

	Treatment									P[1] Values						
	CMR				CMR+											
	Conc		Conc+		Conc		Conc+									
	Fat 18	Fat 12	Fat 18	Fat 12	Fat 18	Fat 12	Fat 18	Fat 12	s.e.	M	C	F	MxC	MxF	CxF	MxCxF
Initial wt. (kg)	55.2	53.2	56.1	57.1	570	54.4	54.1	57.2	2.3	-	-	-	-	-	-	-
Liveweight gain (g/d)																
1-28 days	570	750	760	770	740	820	780	660	82	-	-	-	0.16	0.13	-	-
29-56 days	710	910	930	920	930	900	880	830	88	-	-	-	0.17	-	-	-
1-56 days	640	830	840	840	840	860	830	750	79	-	-	-	0.13	-	0.18	-
1-42 days	620	790	800	820	780	890	830	730	84	-	-	-	0.19	-	0.12	-
57-112 days	1130	1280	1280	1180	1260	1300	1290	990	91	-	-	-	0.19	-	0.03	-
1-112 days	880	1060	1060	1010	1050	1080	1060	870	75	-	-	-	0.12	-	0.04	-

[1]Only P values < 0.20 included.

6. DISCUSSION

6.1 Influence of Increasing Milk Replacer Intake

Generally, higher growth rates during the milk-feeding period were achieved with calves offered 10 l CMR per day resulting in calves with greater live weights at weaning compared with calves offered only 5 l/day. This feeding level effect on growth has been demonstrated in many calf-rearing studies e.g. Steen (1991), Fallon et al., (2005) and Jasper and Weary (2002).

Shamay *et al.* (2005) found that differences in skeletal size, which occurred during the pre-weaning phase, disappeared in the post-weaning phase, this observation was fully supported by results from the current two studies where calves offered high levels of CMR were significantly larger in size at weaning, but differences disappeared by 6 months of age. However, unlike Shamay *et al.* (2005), in the current studies differences in live weight that were significant at weaning were no longer significant at 6 months of age, similar to the findings of Speijers *et al.* (2005).

Although increasing CMR intake may improve growth rates during the first weeks of life, results from the current study and many other neonatal nutrition studies show that increasing the level of CMR feeding negatively influences calf starter intake (Fallon *et al.,* 2005; Speijers *et al.,* 2005). Initiation of calf starter intake in early life is an important requirement for the stimulation of reticulo-rumen development (Williams and Frost, 1992). It has repeatedly been shown that calves receiving a diet of solely milk or CMR have reduced rumen development (Brownlee, 1956; Warner *et al.*, 1956; Stobo *et al.,* 1966), and that solid feed is required for stimulation of the rumen microbial volatile fatty acid (VFA) production. It is the presence of these VFAs that initiates rumen epithelial development (Heinrichs and Lesmeister, 2005). Therefore increasing the level of CMR offered may indirectly slow the development of the rumen (Heinrichs and Lesmeister, 2005). This suggests that there is a fine balance between the level of CMR offered to maximize the growth potential of the calf in early life whilst at the same time ensuring an adequate intake of calf starter concentrate to initiate rumen development.

Daily live weight gain recorded in the study 1 from birth to weaning (day 56) ranged from 0.3 to 0.5 kg/day. These growth rates are within the range reported in the literature for a large range of CMR feed levels but are lower than the high growth rate (≥ 1 kg/day) suggested by Drackley (2002) and observed by Diaz *et al.* (2001). Average growth rates of calves commencing trials from approximately birth (1-8 days) to weaning, which where offered similar CMR feeding levels to the current study of 450-650 g CMR/day and up to 1000 g CMR/day where 0.38 and 0.56 kg per day respectively, which is similar to the growth rates found in the current study for low and high CMR feed levels. Reasons why calves in the current study do not achieve growth rates of 0.6 kg per day or greater could be; average daily gain is from birth until weaning at 56 day unlike studies such as Bartlett *et al.* (2001) where average daily gain is from day 21 to 56; calves are fed in a group penned situation through a computerised milk feeding system which has been shown by Furuhaug et al. (1993) to reduce daily live weight gain compared to individually penned and bucket fed calves, as is used in the majority of studies. Growth rates of 0.7 – 0.9 kg/day have been reported in many studies involving Holstein Friesian calves but in many cases calves have been offered whole milk, suckled (Shamay *et al.*, 2005; Bar Peled *et al.*, 1997) or individually bucket fed (Jasper and Weary, 2002) or with calves that are 2 weeks old at least prior to commencement of the study (Brown *et al.*, 2005; Bartlett *et al.*, 2001a; Fallon *et al.*, 2005). To our knowledge study 1 is the only study that has examined the effect of increasing the level of milk replacer with group-housed calves from birth.

6.2 Influence of Increasing the Crude Protein Content of Milk Replacers

In their study, Blome *et al.* (2003) showed that calves offered higher protein CMRs gained more live weight compared with those offered lower protein CMRs and indicated that calf stature (skeletal size) also increased with increasing dietary protein content. The authors suggested that this demonstrated that the increases in live weight were associated with increased skeletal size and not just gut fill and body fat. Additionally, increasing CP concentration of CMR, while maintaining a constant energy concentration, has been shown to decrease body fat content (Donnelly and

Hutton, 1976a; b; Gerrits *et al.*, 1996; and Bartlett *et al.*, 2001). A point to note when interpreting the study of Blome *et al.* (2003) is that the calves used in the trial were purchased calves and may have been up to 3 weeks old before starting the trial. In study 1, no significant increases in skeletal size or difference in body condition score were found when CMR CP content was increased from 230 to 300 g/kg. Additionally, in the current study, protein content of CMR had no effect on live weight or body condition score at weaning. Altogether the results from studies 1 to 4 suggest that calves offered the higher protein concentration CMR grew no faster from birth to weaning and did not put on additional fat compared with calves offered a low protein CMR.

Unlike the effect of increasing the level of CMR feeding on calf starter intake, increasing the protein concentration did not reduce starter intake in any of the studies. However with no performance benefits observed with increased CMR CP content in the current studies the justification for higher CP intake, without increasing energy intake, is doubtful.

6.3 Long Term Effects of Pre-Weaning Nutrition

Although limited in number, previous research has indicated long-term residual effects of pre-weaning nutrition. Shamay *et al.* (2005) and Bar-Peled *et al.* (1997) have demonstrated relationships between level of nutrition in early life and later milk production. Additionally, Shamay *et al.* (2005) demonstrated a 23 day reduction in age at puberty and Bar-Peled *et al.* (1997) demonstrated a 31 day reduction in calving age for calves offered a higher feed level pre-weaning. These studies had complicating factors such as suckling or fresh milk compared with CMR whereas the current studies involved CMR throughout and found no effect of pre-weaning nutrition on the subsequent lactation performance. Similarly, in the AFBI studies there was no effect of pre-weaning nutrition on age at first oestrus, age at first service or age at successful service. This may have been expected since there were no differences in skeletal size or body weight at six months of age

7. CONCLUSIONS

Although calves offered high levels of CMR grew significantly faster during the milk-feeding period, differences in live weight and body size recorded at weaning (56 days) had disappeared by 6 months. There was no apparent benefit in calf performance of offering CMR containing 300 g CP/kg DM over a CMR containing 230 g CP/kg DM. Lactation performance indicates no benefit of increased CMR feed level or CMR CP content, therefore suggesting that current feed recommendations (~600 g CMR/day, 23% CP) are appropriate for neonatal calf nutrition of dairy bred heifers.

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