Article — Artikel

The effect of unrestricted milk feeding on the growth and health of Jersey calves

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ABSTRACT

This study was conducted to determine the effect of feeding high milk volumes on the growth rate, health and cross-sucking behaviour in group-fed Jersey calves. Three-day-old heifers (n = 120) in a seasonal calving dairy herd were randomly assigned to one of 6 treatment groups. Three groups received high milk volumes (HMV), consisting of *ad libitum* milk or milk replacer feeding twice a day, while 3 groups received restricted milk volumes (RMV), consisting of 2 ℓ twice daily, during the pre-weaning period. After a pre-weaning period during which feeding was reduced to once daily, all calves were weaned at 42 days and monitored until 60 days of age. Adjusting for birth mass, birth date, dam parity and sire, average daily mass gain (ADG), both pre-weaning (days 0–42) and overall (days 0–60), was higher in HMV than in RMV calves ($P < 0.001$). After weaning, growth rates showed no differences and at 60 days of age the HMV calves maintained a 6.74 kg advantage in mean body mass ($P < 0.001$). The mean intake of dry starter feed was higher in RMV than in HMV calves. Overall feed conversion rate of HMV calves was 9.6 % better than RMV calves. However, the variable cost per kg mass gain was 12 % higher for HMV calves. In the RMV groups 75 % of calves showed cross-sucking behaviour pre-weaning and 18 % post-weaning, whereas in HMV calves the proportions were 2 % and 7 %, respectively. There was no significant effect of milk volume on the incidence of diarrhoea. We conclude that the feeding of high volumes of milk to Jersey calves has a positive effect on growth rate, without compromising health or reducing solid feed intake after weaning. However, the higher cost of such a feeding system may limit its implementation.

Keywords: cross-sucking, dairy calves, growth rate, health, unrestricted milk feeding.

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INTRODUCTION

Most dairy producers feed restricted quantities of milk to calves because of cost and the perception that increased milk intake may lead to a higher incidence of diarrhoea, reduced calf starter feed intake and reduced mass gain. Studies have shown that high milk intake may reduce consumption of solid feed during the milk-feeding period[17]. However, restricted milk feeding does not take into account the energy levels required for growth and development[9,33]. Increased milk or milk replacer feeding programmes have resulted in greater growth rates[1,17], but with variable effects on calf health[25,26]. Results from several studies indicate that feeding more milk or high-quality milk replacer does not necessarily cause diarrhoea[17,28,34], the occurrence of which depends more on the pathogen load in the environment, the degree of stress, and the calves' immune status.

From economic, management and welfare perspectives, group housing is in many ways preferable to housing in single pens. The larger accessible area per animal improves the calf's opportunities to satisfy the needs for motion and play[2,18]. Some studies suggest that calves housed individually have lower disease incidence[13], a reduction in behavioural problems such as cross-sucking[21] and higher mass gains[36].

The aim of this study was to test the hypothesis that the feeding of high volumes of milk will increase growth rate and reduce cross-sucking behaviour in group fed calves without compromising their health.

MATERIALS AND METHODS

Calf selection and randomisation

The calves used were from a well-managed Jersey herd in the Western Cape Province of South Africa, with seasonal calving in large open paddocks during January and February. The hot and dry conditions during this time of the year help to ensure a dry and hygienic calving area. Calves were removed from their dams within 8 h of calving and 2 ℓ of fresh, 1st-day colostrum was hand-fed to all calves that did not show obvious physical signs of sufficient intake through natural sucking from their dams. For the 1st 3 days calves were housed indoors in single calf pens and 2 ℓ of 1st-day colostrum was fed twice daily. During this time any calf showing signs of clinical disease or not drinking sufficient colostrum was excluded from the trial. Whole venous blood from each calf was tested with the Quick Test Calf IgG Kit (Midland Bioproducts, Boone, IA, USA) between 48 and 72 h after birth, to ensure that no calf with failure of passive transfer of immunity (FPT) was included in the trial.

Using block randomisation (blocks of 8 consecutively born female calves fulfilling the above inclusion criteria), 120 heifer calves were randomly assigned to one of 3 high milk volume (HMV) or 3 restricted milk volume (RMV) groups as follows:

- HL (high milk volume, large group size): 1 group of 30 calves.
- HS (high milk volume, small group size): 2 groups of 15 calves each.
- RL (restricted milk volume, large group size): 1 group of 30 calves.
- RS (restricted milk volume, small group size): 2 groups of 15 calves each.

Calf housing and feeding

Calves were housed in dry, clean paddocks which, because of the seasonal calving pattern, had housed no other calves during the previous 8 months. The surface area of each small paddock (15 calves) was 400 m^2, while that of large paddocks (30 calves) was 800 m^2, providing a surface area of 26.7 m^2 per calf in all groups. Calves were fed individually according to the liquid feeding schedule in Table 1. Within each group, calves were fed simultaneously at a central milk feeding station using plastic buckets each fitted with a teat. Unrestricted intake was defined as all the milk or milk replacer the calf was able to drink during one feeding,

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culminating in a 2-min period during which no further milk was consumed. Individual milk intake of every calf at every feeding was measured to the nearest 100 mℓ. After 14 days, calves were adapted from fresh milk to a commercially available milk replacer (Meadow Milk Replacer®; 25 % protein, 20 % fat) over a 3-day period. Shade with straw bedding was provided and water and calf starter pellets were available *ad libitum* at all times. Dry matter (DM) content was 13 % for milk and milk replacer and 90 % for starter pellets. The mass of calf starter consumed by each group was recorded daily. All calves were weaned at 42 days of age after gradual weaning (change to once a day milk-feeding and the reduction of milk intake 1 week before weaning, as detailed in Table 1).

Growth and health recording

Calves were weighed and wither height was measured immediately after birth, once weekly throughout the trial, at day 42 (weaning) and at day 60. The health of each calf was appraised visually twice daily by a veterinarian and any calf with severe illness was removed from the study and treated. The number of calves in each group showing cross-sucking behaviour was recorded for 30 min immediately after milk feeding every evening and during the post-weaning period for 30 min each morning. Cross-sucking was defined as any sucking action of a calf directed toward another calf's head or body.

Data analysis

The primary outcome variables were average daily mass gain (ADG) pre- and post-weaning, mortality, morbidity (cumulative incidence and treatment days), cross-sucking behaviour and feed intake (liquid feed and calf starter). With the exception of calf starter intake, all outcomes were measured at the individual animal level. The mean DM intake per calf was calculated, and the gain to feed ratio (G:F) was calculated as the kg mass gained per kg DM intake over the whole trial period. For initial, univariable analysis, continuous outcomes were compared between groups using 1-way ANOVA and binary outcomes were compared using Fisher's exact test. The effect of milk volume on ADG was then estimated using multiple linear regression, adjusting for group size, birth mass, birth date, dam parity and sire. The 1-way interaction between milk volume and group size was also tested. The effect of milk volume on morbidity was estimated using exact logistic regression to model occurrence of disease (yes/no) and negative binomial regression to model treatment days, both methods adjusting for group size and dam parity. The proportions of calves showing cross-sucking behaviour were compared between groups using Fisher's exact test. Statistical analyses were done using Stata 11.1 (StataCorp, College Station, TX, USA). The significance level was set at $\alpha = 0.05$.

Cost analysis

A cost analysis was done using a spreadsheet programme (Excel, Microsoft Corp., Redmond, WA, USA). Costs were calculated on a per head basis over the whole trial period. Only variable costs (liquid and solid feed costs and cost of treatments) were included. Because of the low mortalities, mortality costs were ignored, but other variable costs were averaged over surviving calves.

RESULTS

A total of 114 calves finished the trial, 1 having died due to foreign body pneumonia during the pre-weaning period. During the post-weaning period, 1 calf died and another 4 calves from the RMV groups were removed from the trial due to an outbreak of meningoencephalitis of unknown aetiology.

Milk intake and growth

The pattern of milk intake for the various groups is shown in Fig. 1. During the 1st 35 days HMV calves consumed approximately 3 ℓ (75 %) more milk per day than RMV calves. Within the HMV groups, intake did not differ significantly between group sizes ($P = 0.245$). However, the variation in individual daily milk intake amongst calves within the HMV groups was high, ranging between 2.5 and 12.1 ℓ, with the average daily milk intake varying between 4.8 and 9.2 ℓ/calf.

Mean body mass, wither height and ADG of calves are summarised in Table 2. Weaning mass, day 60 mass, pre-weaning ADG and overall ADG were higher in the HMV groups than the RMV groups

Table 1: **Feeding schedule of calves in high and restricted milk volume groups.**

Time from birth	Restricted milk volume (Groups RL & RS)	High milk volume (Groups HL & HS)
<8 h	2 ℓ fresh day 1 colostrum	
1–3 days	1st-day colostrum: 2 ℓ twice daily	
4–7 days	Colostrum†: 2 ℓ twice daily	Colostrum†: unlimited‡ twice daily
8–21 days	Milk & MR¦: 2 ℓ twice daily	Milk & MR: unlimited‡ twice daily
22–35 days	MR: 4 ℓ once daily	MR: unlimited‡ once daily
36–42 days	MR: 2 ℓ once daily	MR: 3 ℓ once daily
42–60 days	Weaned with only calf starter and water available *ad libitum*	

†Days 2–3 colostrum pooled.
‡ All the colostrum, milk or milk replacer the calf was able to drink during 1 feeding plus another 2 min during which no further milk was consumed.
¦MR: milk replacer.

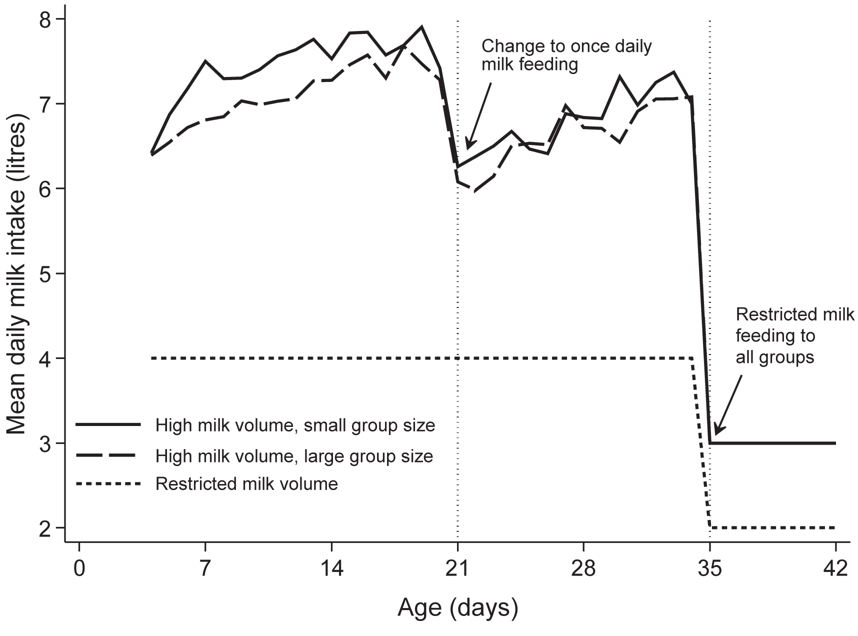

Fig. 1: **Mean daily milk intakes of Jersey heifer calves receiving high and restricted milk volumes**.

($P < 0.05$), but differences in wither height were not significant. Post-weaning growth rates and changes in wither height did not differ significantly between groups.

Adjusted for birth mass, birth date, dam parity and sire, ADG (d0-42 and d0-60) was higher in HMV than RMV calves ($P < 0.001$) (Table 3). There was no significant effect of group size on ADG. The interaction between milk volume and group size was not significant in any of the 3 models.

Mean body mass of calves in the 4 groups, from birth to 60 days, is shown in Fig. 2. The mass advantage of the HMV groups was maintained throughout the trial period, although it was less pronounced for group HL than for group HS. At weaning the mean body mass advantage for the HMV calves *versus* the RMV calves was 6.53 kg ($P < 0.0001$) and at 60 d it was 6.74 kg ($P < 0.0001$).

Table 2: **Mean (±SD) of body mass, wither height and average daily gain in Jersey heifer calves fed high and restricted milk volumes.**

Variable	High milk volume		Restricted milk volume	
	Large group HL	Small groups HS	Large group RL	Small groups RS
Live mass (kg)				
Birth	$22.9^{a} \pm 3.8$	$25.4^{a} \pm 3.6$	$24.0^{a} \pm 3.7$	$23.8^{a} \pm 3.4$
Weaning (d42)	$52.6^{a} \pm 6.2$	$57.1^{b} \pm 7.3$	$48.1^{c} \pm 4.1$	$48.5^{c} \pm 5.8$
Day 60	$64.9^{a} \pm 7.2$	$70.3^{b} \pm 7.7$	$60.6^{a} \pm 5.5$	$61.1^{a} \pm 7.7$
Wither height (mm)				
Birth	$644^{a} \pm 33$	$658^{a} \pm 32$	$653^{a} \pm 31$	$657^{a} \pm 21$
Weaning (d42)	$770^{a} \pm 32$	$778^{a} \pm 30$	$762^{a} \pm 24$	$767^{a} \pm 28$
Day 60	$816^{a} \pm 32$	$821^{a} \pm 31$	$800^{a} \pm 29$	$810^{a} \pm 29$
ADG (kg/d)				
Pre-weaning (d0–42)	$0.71^{a} \pm 0.10$	$0.75^{a} \pm 0.11$	$0.57^{b} \pm 0.06$	$0.59^{b} \pm 0.10$
Post-weaning(d43–60)	$0.68^{a} \pm 0.15$	$0.73^{a} \pm 0.14$	$0.69^{a} \pm 0.18$	$0.71^{a} \pm 0.17$
Total (d0–60)	$0.70^{a} \pm 0.09$	$0.75^{a} \pm 0.09$	$0.61^{b} \pm 0.07$	$0.63^{b} \pm 0.11$

[a,b,c]Means within rows with no superscripts in common differ significantly ($P \leq 0.05$).

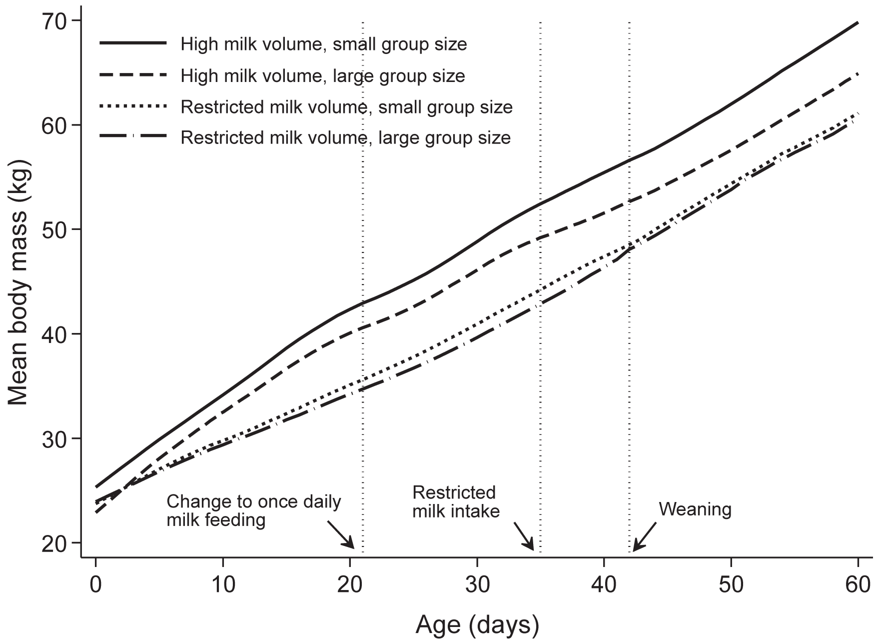

Fig. 2: **Mean body mass of Jersey heifer calves receiving high and restricted milk volumes.**

Disease incidence and treatments

The cumulative incidence of diseases is shown in Table 4. The incidence of pre-weaning diarrhoea ranged between 27 % (group RL) and 64 % (group HS), but with no mortalities due to diarrhoea, whereas the incidence of diarrhoea during the post-weaning period was low. Most cases of diarrhoea were mild, without systemic signs of weakness or dehydration and with the faecal consistency varying from soft to semi-watery. Adjusted for group size and dam parity, the incidence of diarrhoea was not significantly greater in the HMV groups than in the RMV groups, either pre-weaning ($P = 0.240$) or post-weaning ($P = 0.291$), although the number of treatment days was slightly greater pre-weaning (count ratio = 1.71, $P = 0.029$) and overall ($CR = 1.80$, $P = 0.013$).

Except for keratoconjunctivitis, the incidence of disease was low throughout the trial period. Although the pre-weaning incidence of keratoconjunctivitis was not significantly greater in the HMV groups than in the RMV groups ($P = 0.213$), the number of treatment days was greater ($CR = 1.65$, $P = 0.003$). The incidence of other disease (gastrointestinal disturbances other than diarrhoea, arthritis, septicaemia and pneumonia) did not differ between groups either pre-weaning or overall. However, it was significantly higher post-weaning in the RMV groups ($OR = 15.4$, $P = 0.002$), mainly due to a small outbreak of meningoencephalitis.

Dry feed and weaning

Differences in solid feed intake between groups were negligible until the 4th week of the trial. However, up to the 7th week of the trial, mean intake of starter pellets was more than 50 % higher in the RMV groups than in the HMV groups. During

Table 3: **Multiple regression models: effect of milk volume and group size on average daily gain** (ADG) **in Jersey heifer calves, adjusted for birth mass, birth date, dam parity and sire.**

Outcome	Variable and level	*b*	SE(*b*)	95 % confidence interval (*b*)	*P*-value
ADG from birth to weaning (42 days)	Milk volume (HMV *vs* RMV)	0.154	0.017	0.121, 0.187	<0.001
	Group size (large *vs* small)	–0.020	0.017	–0.054, 0.013	0.237
ADG from weaning to 60 days	Milk volume (HMV *vs* RMV)	–0.002	0.030	–0.062, 0.058	0.944
	Group size (large *vs* small)	–0.046	0.031	–0.107, 0.014	0.133
ADG from birth to 60 days	Milk volume (HMV *vs* RMV)	0.104	0.017	0.071, 0.137	<0.001
	Group size (large *vs* small)	–0.027	0.017	–0.061, 0.006	0.109

Table 4: **Cumulative incidence (%) of diarrhoea, keratoconjunctivitis and other disease in Jersey heifer calves fed high and restricted milk volumes.**

	High milk volume			Restricted milk volume		
	Large group (HL)	Small groups (HS)	Mean	Large group (RL)	Small groups (RS)	Mean
Diarrhoea						
Pre-weaning	33 [a]	64 [b]	48	27 [a]	47 [ab]	37
Post-weaning	14 [a]	11 [a]	12	3 [a]	7 [a]	5
Overall	41 [ab]	64 [b]	53	30 [a]	50 [ab]	40
Keratoconjunctivitis						
Pre-weaning	90 [a]	79 [ab]	84	83 [ab]	63 [b]	73
Post-weaning	72 [a]	61 [a]	67	60 [a]	63 [a]	62
Overall	100 [a]	93 [a]	96	90 [a]	83 [a]	87
Other						
Pre-weaning	17 [a]	18 [a]	17	3 [a]	10 [a]	7
Post-weaning	0 [a]	0 [a]	0	10 [ab]	23 [b]	17
Overall	17 [a]	18 [a]	17	13 [a]	30 [a]	22

[a,b,c] Means within rows with no superscripts in common differ significantly ($P < 0.05$).

the last 3 weeks of the trial, the differences in average consumption of solid feed between the groups were less than 0.1 kg/calf/day. Over the whole trial period, the mean intake of starter pellets was 61.0 kg for RMV calves and 55.2 kg for HMV calves.

Feed conversion and cost

Average gain-to-feed ratio (G:F) and cost of rearing over the whole trial period are given in Table 5. Because starter ration intake was not measured at the individual animal level, it was not possible to compare these between groups. There was approximately a 10 % better G:F of calves in HMV groups compared with calves in the RMV groups. However, the average feed and treatment costs were about R250 (almost 35 %) more for calves in the HMV groups. The cost per kg of live mass gain was on average just over 10 % higher for calves in the HMV groups.

Cross-sucking

The proportion of calves showing cross-sucking behaviour during the pre-weaning period was 75 % in RMV groups *vs* 2 % in HMV groups ($P < 0.001$). During the post-weaning period this decreased to 18.4 % in the RMV groups and increased to 7.3 % in the HMV groups, the difference remaining significant ($P < 0.001$).

General observations

Subjectively, the rate of ingestion was higher, butting during drinking was more aggressive and attempts at milk stealing were more frequent in RMV than in HMV calves. Calves in the HMV groups spent far more time in social behaviour, including locomotor play such as pushing and butting each other and running around in the paddocks. This was especially noticeable in the 30 min after milk feeding, while calves in the RMV groups were largely busy with cross-sucking.

DISCUSSION

The 1st objective of this study was to determine the effect of high liquid intake in dairy calves on growth performance, starter intake, weaning transition and post-weaning growth. The results confirmed that the milk intake of calves with unrestricted milk allowance (as defined in our protocol) was far greater than in standard dairy management programmes. This is consistent with several studies showing that calves have the ability to consume large volumes of liquid feeds of approximately 16 % to 24 % of body mass[9,11,20]. The considerable between-calf variation in milk intake among HMV calves is consistent with previous reports[1,30].

The faster pre-weaning growth of the HMV calves compared with the RMV calves confirmed that the growth of milk-fed calves is proportional to the amount of milk provided[15,20]. As might be expected, starter intake was negatively influenced by higher milk intake, which is in agreement with other studies[17,35]. The pre-weaning ADG of the HMV calves in this study compared well with expected growth rates of between 0.6 and 0.8 kg/day for Holstein calves on enhanced early nutrition programmes[11]. This was surprising for Jersey calves, but may partly be

Table 5: **Average gain-to-feed ratio and cost analysis for Jersey heifer calves fed high and restricted milk volumes.**

	High milk volume			Restricted milk volume		
	Large group (HL)	Small groups (HS)	Mean	Large group (RL)	Small groups (RS)	Mean
Dry matter intake per calf (kg)	80.4	81.6	81.0	73.9	72.2	73.1
Live mass gained per calf (kg)	54.7	56.4	55.6	44.8	47.8	46.2
G:F (kg BM/kg DM)	**0.68**	**0.69**	**0.69**	**0.61**	**0.66**	**0.63**
Cost/calf surviving						
Feed (R)	907.00	903.27	904.87	626.66	692.32	657.70
Treatment (R)	53.60	57.68	55.68	35.86	75.77	54.73
Total (R)	**960.60**	**960.95**	**960.54**	**662.52**	**768.09**	**712.43**
Cost/kg live mass gain of surviving calves						
Feed (R)	16.57	16.03	16.28	14.00	14.48	14.24
Treatment (R)	0.98	1.02	1.00	0.80	1.58	1.19
Total (R)	**17.55**	**17.05**	**17.28**	**14.80**	**16.07**	**15.43**

explained by differences in study design. It is also possible that lower maintenance requirements in Jerseys may have compensated for any genetic disadvantage in growth rate. The effect of milk volume on pre-weaning ADG was less than in some other studies. Work on calves of similar ages showed larger differences in rates of gain for *ad libitum vs* calves fed restricted milk volumes: 0.85 kg/day *vs* 0.36 kg/day[1], 0.78 kg/day *vs* 0.48 kg/day[17] and 0.53 kg/day *vs* 0.11 kg/day[34]. This might partly be explained by higher milk allowances (more than 10 % of body mass) to the RMV calves in our study, the relatively short period (days 4–35) of unrestricted milk allowance, the change to once daily feeding at day 21, and the fact that in some studies milk was offered *ad libitum* throughout the day with no concentrate consumption.

Although restricted rates of liquid feeding do not support maximum mass gains, they do encourage earlier intake of starter feeds, which promotes rumen development, a smoother weaning transition and earlier weaning[6]. Post-weaning growth and weaning stress are mainly determined by starter intake[23]. Some studies report that the transition from milk to solid feed may cause a lag in growth and lower post-weaning gain when the pre-weaning milk allowance is high[16,29]. However, this study showed no difference in the smoothness of weaning between groups and no evidence of lower intakes after weaning. These results concur with other studies that the growth advantage of calves on enhanced early nutrition programmes can be maintained after weaning[17]. In this study, calf starter intake was stimulated by the change to once a day milk-feeding and the reduction of milk intake 1 week before weaning. Milk volume reduction over a period is considered to be the preferable weaning method because of the higher concentrate intake during and after weaning and because of the lower activity shown by these calves during the weaning period[24].

Another important objective of this study was to investigate the possible effects of high volumes of a liquid diet on dairy calf health. In general, the results indicated that the incidence of important health disorders was similar across treatment groups and that the health of the calves was not affected by the volume of liquid feed intake. The mortality rate was very low (<1 %) during the pre-weaning period. Reported mortality risk of neonatal calves varies between 15 and 30 %[22,32], with diarrhoea accounting for between 21 % and 62 % of calf losses in the USA[32].

Recommendations to restrict liquid intake are based on the belief that feeding greater volumes will cause a nutritional diarrhoea[6]. However, in this study there was no significant effect of milk volume on the incidence of diarrhoea. This is consistent with other studies showing that merely feeding more milk does not necessarily result in diarrhoea[15,17,25]. The level of microbial contamination in a calf-raising environment appears to be more important than the amounts of high quality liquid feeds consumed in altering the delicate balance of intestinal tract microbes and conditions of increased bacterial challenge, such as poor calving management, sanitation or calf housing, will increase the risk of calf diseases[6,10]. In this study, good management practices, including colostrum management and favourable environmental conditions on the farm (outside calving paddocks and dry warm weather), were likely responsible for the low incidence of important diseases such as diarrhoea, pneumonia and septicaemia. The results from this study therefore indicate that, under conditions of good management and sanitation, high milk volume intake does not necessarily lead to diarrhoea.

The incidence of diseases other than diarrhoea and keratoconjunctivitis was very low in all the groups. The 2 cases of pneumonia during the trial are in contrast with the general trend in the USA, where pneumonia is responsible for 21.3 % and 50.4 % of pre-weaned and weaned heifer deaths, respectively[32].

The high incidence of keratoconjunctivitis throughout the trial was probably due to well known risk factors such as dry dusty conditions, ultraviolet exposure, flies and *Moraxella bovis* which was isolated on the farm. The diagnosis was made in the very early stages of the disease and intra-ocular antibiotic treatment was successful.

Our results confirm those of a previous study that hunger during the milk-fed stage stimulates cross-sucking behaviour[1]. Calves fed restricted quantities of milk were more likely to have consumed their entire milk ration before negative feedback mechanisms associated with satiety took effect, so the cross-sucking performed immediately after a milk meal is likely related to hunger[27,34]. The sucking under the belly and especially on the udder observed in this trial was of special concern as it may result in cross-sucking amongst heifers and cows, with subsequent negative effects on udder health and milk production[19,21]. The slight increase in the incidence of cross-sucking by the HMV calves around weaning is consistent with the findings of a previous study[7], *i.e.* that calves that perform cross-sucking are often underfed at weaning, and it is possible that more gradual weaning could have prevented this[24]. The large reduction in cross-sucking behaviour of the RMV calves just after weaning may be explained by the fact that there was no longer any stimulation by the ingestion of milk and consequently no redirection of the natural sucking behaviour, as suggested by de Passillé & Rushen[8]. Furthermore, the increased intake of solid feeds after weaning would also have reduced cross-sucking behaviour[19,29]. It appeared that social facilitation also played a role in the occurrence of cross-sucking behaviour. When 1 animal performed cross-sucking, the likelihood (subjectively assessed) that nearby calves would start cross-sucking increased. Nevertheless, our results show that unrestricted milk feeding allows calves to be housed in groups with only a very low incidence of cross-sucking.

Group housing of neonatal calves may provide more calf-to-calf contact and enrichment stimulus compared with individual housing[2,14]. Play behaviour has been suggested to be an indicator of good welfare in calves[18]. The greater tendency to perform locomotor play in the HMV calves may therefore be an indication of better welfare conditions of calves receiving higher milk volumes.

Results from this study are consistent with previous research that showed better feed conversion rates of HMV calves[4,9,20] . These studies observed feed to live mass efficiencies of 0.75 to 0.80 for pre-ruminant calves fed for *ad libitum* consumption, which is marginally better than the G:F found in HMV calves in our study (0.69). The slight tendency toward a better G:F in the smaller groups during the trial can perhaps be explained by less locomotor activity in the smaller paddocks.

In the USA, accelerated growth programmes generally cost $35 to $50 more per calf than conventional programmes[5], similar to the difference observed in our study (approximately R250). The 35 % greater cost of raising the HMV calves could largely be attributed to their 72 % greater milk consumption. However, the return on this investment is more difficult to define. Previous work has shown that early body mass advantages can result in lower age at 1st calving, reduction in the costs of production[31], increased mature body mass and higher 1st lactation milk production[3,12]. It appears that the biology of the calf allows for rapid growth during the first few weeks of life. If this early opportunity for rapid gains is not met, high levels of intake later in life may not allow for compensatory growth. From a biological perspective it would be difficult to argue that improving nutritional status of the young calf during the first few weeks of life should be anything but positive for subsequent productivity. However, follow-up studies measuring long-term production and reproductive performance are required to determine the return on investment of HMV feeding in dairy calves.

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