Performance and health responses of dairy calves offered different milk replacer allowances

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ABSTRACT

Eighty female Holstein calves (12 ± 4.1 d of age and 42 ± 4.3 kg of BW) were collected from different herds, brought to the study site, and blocked by age and assigned to either a 6 L/d maximum daily milk replacer (MR) allowance (LMR) or a maximum MR allowance of 8 L/d (HMR). Calves were kept in individual hutches until 52 d of age and then moved into pens, forming groups of 10. All calves had ad libitum access to a mash starter feed. Calves in both treatments received the MR distributed in 3 separate allotments between 1 wk after the beginning of the study and 52 d of age. Then, all calves were moved to group pens and preweaned by offering 2 L/calf of the same MR twice daily in a trough until the age of 59 d, when MR offer was further reduced to a single dose of 2 L until the age of 73 d, when all calves were completely weaned. Individual starter feed and MR consumption was recorded on a daily basis until 52 d of age, and on a group basis until weaning time. Body weight was measured at the beginning of the study and at 52 (preweaning), 73 (weaning), and 110, 160, and 228 d of age. Solid feed consumption (mean $\pm$ SE) was greater in LMR (821 ± 42.1 g/d) than in HMR calves (462 ± 42.1 g/d) between 42 d of age and 52 d (preweaning). As expected, as age increased, solid feed consumption increased, and LMR showed a more marked increase than HMR calves. Despite the greater solid feed intake of LMR calves, HMR grew faster than LMR calves until preweaning time, but from preweaning to weaning, LMR calves grew more than HMR calves (977 vs. 857 $\pm$ 30.7 g/d, respectively; mean $\pm$ SE). No differences in feed efficiency were observed. While calves were individually housed, no differences were observed in the incidence of bovine respiratory disease or diarrhea between treatment groups. We concluded that, under the milk regimen, age range of calves, and weaning method used in the current study, before preweaning,

HMR calves grow more than LMR calves, but between preweaning and weaning, LMR grow more than HMR calves, overcoming the difference in BW at preweaning. As a result, with the weaning scheme followed herein, providing more milk does not ensure greater performance; no differences are obtained in BW at weaning and at 228 d of life. Also, based on solid feed consumption patterns seen in this study, we determined that the optimum age to reduce MR allowances and foster solid feed intake is around 45 d of age.

Key words: efficiency, intake, starter

INTRODUCTION

For several decades, milk offered to calves has been restricted to keep feed and labor costs low (Kehoe et al., 2007) and foster solid feed intake and rumen development (Davis and Drackley, 1998). More recently, it has been shown that fostering rapid growth early in life may have positive consequences on future milk performance (Bach and Ahedo, 2008; Bach, 2012; Soberon et al., 2012) and survivability to second lactation (Bach, 2011). If rapid growth (>700 g/d) is sought, feeding increased amounts of milk is necessary. However, calves fed high milk allowances tend to struggle during transition onto solid feed, and part of the growth advantage achieved before weaning is lost due to (1) diminished consumption of nutrients (Davis and Drackley, 1998) and (2) reduced digestibility (Terré et al., 2007; Hill et al., 2010), most likely due to insufficient development of the reticulorumen (Baldwin et al., 2004) and inadequate establishment of the rumen microflora (Terré et al., 2007) as a consequence, in part, of the weaning method used (too abrupt in many instances). Gradually weaning calves over an extended period of time has been proposed as a solution to minimize these negative consequences (Khan et al., 2007; Roth et al., 2009). Another alternative has consisted of offering poor-quality chopped hay (Castells et al., 2012) before weaning to foster solid feed intake (Castells et al., 2013; Montoro et al., 2013).

On the other hand, the effect of providing increased amounts of milk or milk replacer (MR) on health

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seems to be inconsistent. A priori, one would expect that offering more MR would improve animal health due to improved supply of nutrients, but some studies report increased diarrhea (Huber et al., 1984; Quigley et al., 2006) and impaired response to vaccination (Pollock et al., 1994), some report no changes (Nonnecke et al., 2003; Borderas et al., 2009), and some others report improvements in health (Nocek and Braund, 1986). Furthermore, to our knowledge, previous studies have focused on diarrhea and the potential effect of high MR allowances on bovine respiratory disease (BRD) has only been assessed by Borderas et al. (2009). Furthermore, most of the studies that evaluate the effect of milk allowance in young calves end at weaning or about 2 wk after weaning (Díaz et al., 2001; Cowles et al., 2006; Hill et al., 2009). The objectives of this study were to evaluate the short- and medium-term effects on growth performance and health of calves receiving 2 different milk allowances.

MATERIALS AND METHODS

Animals and Experimental Design

Eighty female Holstein calves (12 ± 4.1 d of age and 42 ± 4.3 kg of BW) were collected from 43 dairy herds and brought to the study site (Rancho Las Nieves, Mal-lén, Spain) on June 6, 2012. Upon arrival, calves were blocked by age (one block of 40 calves with an age of 9 ± 2.6 d and initial BW of 41 ± 3.5 kg, and a second block of 40 more calves with an age of 16 ± 1.4 d and initial BW of 43 ± 4.6 kg) and then randomly assigned (which should remove any potential carryover effects of previous life experience before entering the study) to either a maximum daily MR allowance of 6 L/d (LMR) or 8 L/d (HMR). All calves in both treatments were managed similarly under the approval and supervision of the Animal Care Committee of the Institut de Recerca i Tecnologia Agroalimentàries (IRTA, Barcelona, Spain). Calves were kept in individual hutches (1×1.6 m) until 52 d of age. Therefore, calves that entered the study at 9 d of age spent 1 more week (42 d in total) in individual hutches than calves that entered at 16 d of age (spent a total of 35 d). Calves were moved into pens (6×3 m) in groups of 10 animals, with an average age of 52 d. Calves were bedded with chopped straw every other day. From enrollment in the study, all calves had ad libitum access to a mash starter feed (Table 1) and water, and were bottled-fed 2 L of MR (25% CP, 19% fat, and 5.18 Mcal of gross energy/kg) at a 10% dilution rate 3 times per day (at 0700, 1500, and 2200 h) during the first week of the study to ease the adaptation of the calves to new environment and MR (as commonly done in contract heifer operations).

Then, calves in the LMR group continued to receive 6 L of MR/d in 3 separate doses (at the same times as in the first week) but at a 12.5% dilution rate, whereas calves in the HMR received 8 L of MR/d at 12.5% distributed in 3, 3, and 2 L at 0700, 1500, and 2200 h, respectively. At the age of 52 d, all calves were moved to pens and were preweaned by offering 2 L/calf of the same MR (at 12.5% dilution) at 0700 and 1500 h in a trough until the age of 59 d (4 L/d). Then, at 59 d of age, MR offer was further reduced to a single daily dose of 2 L at 12.5% dilution rate at 0700 h until the age of 73 d, when all calves were completely weaned. When moving calves out of the individual hutches, groups were formed exclusively with animals pertaining to the same treatment (i.e., all LMR calves were distributed in 4 different pens, and all HMR calves were distributed in 4 additional pens).

When calves were moved to groups, they continued to receive the same starter feed as that received when individually housed and 1 wk later were moved to a dry TMR (Table 1) until 110 d of life. Then, they received a different dry TMR until the age of 160 d (Table 1), and then another TMR (Table 1) until the age of 228 d. After weaning, all animals were handled and fed in exactly the same manner.

All calves were weighed using an electronic scale upon arrival, and at 52 (preweaning), 73 (weaning), and 110, 160, and 228 d of age. Individual starter feed and MR consumption was recorded on a daily basis until 52 d of age, and on a group basis until weaning time (73 d of age). Throughout the study, on a daily basis, each calf was checked for incidence of diarrhea or BRD. A calf was considered to have diarrhea when assigned a fecal score ≥ 3 using a 4-point scale following Larson et al. (1977): 1 = firm, 2 = soft, 3 = runny, and 4 = liquid. Similarly, an animal was considered to have BRD when she presented 1 or several of the following signs: labored breathing, coughing, droopy ears, eye discharge, or nasal discharge along with a fever.

Last, starter feed and TMR were analyzed for DM (24 h at 103°C), N content using the AOAC (1990) method (988.05) adapted for an automatic distiller Kjeldahl (Kjeltec Auto 1030 Analyzer; Tecator AB, Höganäs, Sweden) and using CuSO_4/Se as a catalyst instead of $\text{CuSO}_4/\text{TiO}_2$; ether extract using the AOAC (1990) method (920.39), using petroleum ether for distillation instead of diethyl ether; and NDF and ADF following Van Soest et al. (1991), with sodium sulfite and heat-stable α -amylase.

Calculations and Statistical Analysis

Data pertaining to BW and ADG from entrance until preweaning (52 d of age) were analyzed using an

Table 1. Ingredient and nutrient composition of the starter feed and the TMR used in the current study

Item	Starter feed	TMR (59 to 110 d)	TMR (111 to 160 d)	TMR (161 to 228 d)
Ingredient, % of DM				
Ryegrass hay	—	4.9	25.1	—
Wheat straw	—	3.2	5.8	19.9
Corn silage	—	—	—	5.2
High-moisture corn	—	—	—	12.7
Brewers grains	—	—	—	5.7
Wheat middlings	29.6	27.2	14.7	9.9
Corn (cracked)	20	35.4	32.3	16.5
Oats (whole)	19.6	5.5	—	—
Soybean hulls	8.4	6.7	8.8	4.8
Soybean meal	8	11	11	1.5
Sunflower meal	—	—	—	9.4
Canola meal	—	—	—	12.7
Corn gluten meal	7.3	2.5	—	—
Carob	5.2	2	—	—
Molasses	—	—	1.5	1.1
Calcium carbonate	0.8	0.7	0.4	0.3
Sodium chloride	0.5	0.5	0.2	0.2
Vitamin/trace mineral premix ¹	0.4	0.4	0.2	0.1
Nutrient ²				
DM, %	89	88.8	88.2	64.3
CP	20.4	17.7	16.9	16.6
Ether extract	4.1	3.5	3.1	3.2
NDF	20.5	26.6	30.6	35.6
ADF	8.7	12.8	16.98	21.3
ME, ³ Mcal/kg	3.46	3.02	2.89	2.47

¹The premix for the starter provided (on a DM basis) 1 kIU of vitamin A/kg, 120 IU of vitamin D/kg, 10 IU of vitamin E/kg; 3,000 mg of Cu/kg, 5,000 mg of Mn/kg, 90 mg of I/kg, 9,300 mg of Zn/kg, 22 mg of Co/kg, 90 mg of Se/kg, and 4,000 mg of Fe/kg.

²Percentage of DM (unless otherwise indicated), determined as described in the text.

³Calculated according to NRC (2001).

ANOVA that accounted for the effects of block (age of entrance) and treatment. Data pertaining to starter feed and MR intake from entrance until preweaning (52 d of age) were analyzed using a mixed-effects model that accounted for the fixed effect of block (age of entrance; either 9 or 16 d), treatment, day, and the interaction between day and treatment, and the random effect of calf within treatment. Day entered the model as a repeated measure with an autoregressive order 1 variance-covariance structure, which yielded the smallest Bayesian information criterion. Initially, a model similar to the one described above was run, including the random effect of herd of origin, but because this effect had no significant effect it was removed from the final model.

The data pertaining to starter feed and nutrient intakes, BW, and ADG from preweaning to completion of the study were analyzed using a mixed-effects model that accounted for the fixed effects of block (age of entrance; either 9 or 16 d), treatment, time, and the interaction between treatment and time, plus the random effect of pen within treatment, with pen as the experimental unit. Time entered the model as a repeated measure using an autoregressive order 1 vari-

ance-covariance structure, which yielded the smallest Bayesian information criterion.

Feed efficiency was calculated by dividing BW accretion by total DMI (both starter feed and MR). Potential differences in feed efficiency were then assessed using an ANOVA, with the effect of treatment and age group (block) for the data pertaining to the period between entrance and preweaning (52 d). Once animals were grouped until weaning (73 d of age), feed efficiency was assessed on a pen basis ($n = 4$), and data were analyzed as a 2-level mixed-effects model that accounted for the dependence of calves within pen, including the fixed effects of block (age of entrance; either 9 or 16 d) and treatment, plus the random effect of pen and animal within pen.

Incidences of diarrhea and BRD were summarized individually until preweaning (52 d) and per pen ($n = 4$) after grouping. Data were analyzed using logistic regression and odds ratios (**OR**) for diarrhea, BRD, and relapses and were calculated with the LMR group as the reference group. Therefore, an OR of 1 represents an equal likelihood of disease in a particular group, whereas an OR > 1 indicates a greater likelihood of that particular disease occurring relative to the LMR.

RESULTS AND DISCUSSION

Animal Performance

Calves entered the study with an average age of 12 d and were grouped in 2 blocks according to age (9 and 16 d). Interestingly, the effect of block (age of entrance) had no effect on overall BW ($P = 0.13$) and only tended to result in an overall greater ADG (mean $\pm$ SE) in calves entering at 9 d old (998 ± 20.4 g/d) than in those entering at 16 d of age (955 ± 16.7 g/d). However, calves that enrolled in the study at 9 d of age tended ($P = 0.06$) to consume less dry feed (302 ± 30.0 g/d) up to 52 d of age than calves that enrolled at 16 d of age (384 ± 30.1 g/d; data not shown). Nevertheless, a model that included the interaction between age of entrance and treatment was run for all parameters and in no case was the interaction found to be less than $P = 0.20$, which would suggest that any potential effects of feeding and management before entering the study were cancelled by the randomized allocation of calves to treatments.

Due to the experimental design, MR consumption until 52 d of age was greater ($P < 0.001$) in HMR than in LMR calves (Table 2). As a consequence, LMR calves consumed more ($P < 0.001$) solid feed than HMR calves (Table 2) until 52 d of age. Several authors have reported that solid feed consumption decreases as MR allowance increases (Khalili et al., 1992; Jasper and Weary, 2002; Terré et al., 2006), although some have reported increased starter feed intake when feed-

ing more MR (Kristensen et al., 2007; Hill et al., 2009). Also as expected, as age increased, dry feed consumption increased ($P < 0.001$), but LMR showed a more marked ($P < 0.001$) increase compared with HMR calves (Figure 1). After 30 d of the study, LMR calves clearly consumed more starter than HMR calves, suggesting that perhaps about 45 d of age would be a good moment to reduce MR offered to HMR calves to foster solid feed consumption and avoid the slump in ADG following weaning commonly observed when offering large milk allowances. However, despite the greater solid feed intake of LMR calves, HMR grew faster ($P < 0.003$) than LMR calves until preweaning time (Figure 2), because total energy and protein consumption was greater ($P < 0.001$) in HMR than in LMR calves until 52 d of age (Table 2).

From preweaning to weaning, all calves received the same amount of MR and no differences were observed in solid feed intake ($n = 4$). However, LMR calves had a greater ($P < 0.05$) ADG (of more than 100 g/d) than HMR calves (Figure 2). One reason for the greater ADG in LMR than HMR calves during preweaning could be that the reduction of MR from 8 to 4 L/d in HMR calves was too abrupt and calves struggled to improve solid feed intake (which was about 120 g/d numerically lower than in LMR calves). This might have been avoided by a more gradual reduction in MR allowance and highlights the potential importance of the weaning strategy when feeding large amounts of milk. Another reason to explain the improved ADG in

Table 2. Intake and performance of calves as affected by level of milk replacer (MR): 6 L of MR/d (LMR) versus 8 L of MR/d (HMR)

Item	Treatment			P-value		
	LMR	HMR	SE	Treatment (Trt)	Time (T)	Trt $\times$ T
Initial BW (12 d), kg	41.8	41.7	0.66	0.89	—	—
BW at preweaning (52 d), kg	68.9	72.6	1.06	0.02	—	—
BW at weaning (73 d), kg	89.4	90.6	1.66	0.60	—	—
BW at 228 d, kg	252.1	252.9	2.21	0.69	—	—
ADG (12 to 228 d), g/d	967	985	15.9	0.42	<0.001	0.003
MR intake, ¹ g/d						
Until preweaning	721	926	0.55	<0.001	—	—
Prewaning to weaning	333	333	0	—	—	—
Starter feed intake, ¹ g/d						
Until preweaning	413	272	30.0	<0.001	—	—
Prewaning to weaning	2,078	1,891	95.9	0.20	—	—
Energy intake, ¹ Mcal of ME/d						
Until preweaning	4.16	4.68	0.093	<0.001	—	—
Prewaning to weaning	6.13	5.57	0.321	0.20	—	—
CP intake, ^{1,2} g/d						
Until preweaning	231	258	5.33	<0.001	—	—
Prewaning to weaning	353	321	15.1	0.20	—	—
Feed efficiency, ^{1,2} %						
Until preweaning	57.2	59.2	0.95	0.13	—	—
Prewaning to weaning	46.7	44.8	1.28	0.37	—	—

¹Results for preweaning correspond to data collected individually ($n = 40$), whereas intake values between preweaning and weaning correspond to data collected by group ($n = 4$).

²Feed efficiency was calculated as BW accretion divided by total DMI (starter feed plus MR) expressed as percent ($\times 100$).

Figure 1. Evolution of dry feed intake during the first 42 d of the study as affected by the level of milk replacer (MR). Open circles denote 8 L of MR/d (HMR) and solid circles depict 6 L of MR/d (LMR). Asterisks indicate days of study when dry feed consumption differed ($P < 0.05$) between LMR and HMR calves. Error bars represent the SE at each time point.

LMR compared with HMR calves in the absence of a difference in starter feed (although numerically it was also greater) and MR intakes could lead to a potential increase in DM digestibility. Terré et al. (2007) reported that calves fed relatively large amounts of MR (up to 1,260 g of DM/d) had lower DM and NDF digestibilities compared with calves fed low amounts of MR (up to 500 g of DM/d) during the week after weaning. More recently, Hill et al. (2010) reported similar findings when comparing MR allowances of 0.66 versus 1.09 kg of MR/d. A third possibility could be that the relatively more abrupt reduction in MR allowance in HMR than in LMR calves may have increased the stress level in the former group of calves and increased competition for the MR when offered in a trough. However, this hypothesis is unlikely because no differences in coefficient of variation in ADG (that could be used as a proxy for

intake) between the HMR and LMR groups were found during both preweaning (12.6 ± 1.56 vs. $13.2 \pm 1.56\%$, respectively; $P = 0.66$) and after weaning (23.5 ± 4.23 vs. $20.5 \pm 4.23\%$, respectively; $P = 0.48$). In fact, Bach et al. (2010) reported that when calves are weaned in groups, they do better in terms of performance and health (and most likely have a lower level of stress) than calves weaned in isolation.

After weaning (73 d), no differences were observed in ADG between LMR and HMR calves up to about 7 mo of age (Figure 2). Thus, BW of calves at weaning (73 d of life) was not affected by MR allowance and final BW at 228 d of life was not different between the 2 treatments (Table 2). Part of the lack of differences in BW and ADG was probably due to the method of weaning imposed in this study, which may have been too aggressive for the HMR calves.

Figure 2. Evolution of ADG (g/d) with age as affected by the level of milk replacer (MR) offered. Open circles denote 8 L of MR/d (HMR) and solid circles depict 6 L of MR/d (LMR). Error bars represent the SE at each time point.

Feed efficiency was not affected by MR allowance (Table 2). In general, when comparing an allowance of approximately 500 g/d with allowances up to 1,000 g/d, feed efficiency increases as MR allowance increases (Huber et al., 1984; Terré et al., 2007; Hill et al., 2009). In the current study, only numerical improvements in feed efficiency were observed in HMR compared with LMR before preweaning, and between preweaning and weaning this numerical difference was reversed. The proportion of total DMI that was consumed in the form of starter feed (data not shown) between the beginning of the study and preweaning time (52 d) was greater ($42.1 \pm 3.14\%$) in LMR compared with HMR calves ($22.6 \pm 3.14\%$). Interestingly, within the LMR calves, those that consumed more solid feed (and thus had a greater percentage of the DM consumed in the form of solid feed) before preweaning were more efficient ($P < 0.05$) than those that consumed less solid feed (Figure 3A). However, within the HMR calves, no correlation was observed between the proportion of solid feed intake and feed efficiency (Figure 3B). Three potential reasons exist to explain the lack of response in feed efficiency in HMR calves as the proportion of solid feed in the form of starter increased. The first reason could be that HMR calves were at their maximum growth conversion efficiency. However, other studies (Bach et al., 2007; Terré et al., 2007; Stamey et al., 2012) have reported greater feed efficiencies than the ones reported herein;

Figure 3. Relationship between starter feed intake before preweaning (d 52 of life) as a proportion of total DMI and feed efficiency as affected by milk replacer (MR) allowance. (A) Calves consuming 6 L of MR/d ($R^2 = 0.16$; $P = 0.02$). (B) Calves consuming 8 L of MR/d ($R^2 = 0.001$; $P = 0.83$). Color version available in the online PDF.

thus, this reason seems unlikely. A second potential reason could be that as more MR is offered, digestibility of the starter feed decreases, as reported elsewhere (Terré et al., 2007; Hill et al., 2010), and thus the additional nutrients consumed are not efficiently utilized. A third potential reason could be a decreased insulin sensitivity of HMR due to the relative large volume MR supplied. Increases of insulin resistance have been associated with a tendency toward fattening (Sillence, 2004) and, thus, feed efficiency should worsen (Hostettler-Allen et al., 1994). Bach et al. (2013) showed that providing 8 L of MR/d in 2 daily allotments of 4 L each induced an

Table 3. Incidence and odds ratio (OR) of pathology as affected by level of milk replacer (MR) offered and age at entrance: 6 L of MR/d (LMR) or 8 L of MR/d (HMR)¹

Pathology	LMR	HMR	OR: LMR vs. HMR	95% CI ²	P-value
Bovine respiratory disease					
Individually housed (<52 d), %	12.5	12.5	1	—	1.0
Relapses, % of affected	60.0	0.0	—	—	0.04
Group housed (53–110 d), %	7.5	5.0	1.59	1.02–2.34	0.63
Relapses, % of affected	0.0	50.0	—	—	0.14
Diarrhea					
Individually housed (<52 d), %	52.5	45.0	1.38	0.98–2.02	0.49
Relapses, % of affected	4.8	20.0	0.17	0.02–0.88	0.10
Group housed (53–110 d), %	0.0	2.5	0.00	—	0.23
Relapses, % of affected	—	0.0	—	—	—

¹Results for individually housed calves correspond to data collected individually (n = 40) and results pertaining to group-housed calves correspond to data collected by group (n = 4).

²Confidence interval for OR.

increase in insulin resistance in calves compared with calves that received 4 L of MR/d (2 L per allotment). However, in that study, calves were fed MR in 2 daily allotments and the authors actually hypothesized that if more daily allotments were offered (as herein), the results may differ.

Incidence of Disease

Regarding health status, while calves were individually housed, no differences were observed in the incidence of BRD (Table 3); however, 60% (3 calves) of the LMR calves affected by BRD had a relapse while individually housed, whereas no calves in the HMR relapsed during that period. Diarrhea incidence was much greater than that of BRD while calves were individually hutched; however, it did not differ between treatment groups. Interestingly, though, 62.5% of the calves that entered the study at 9 d of age experienced diarrhea (data not shown), and this number was greater ($P = 0.01$) than the 35% diarrhea cases recorded in the calves that entered the study at 16 d of age (independent of the assigned treatment).

Contrary to what occurred with BRD, HMR calves that experienced diarrhea tended ($P = 0.10$) to be more likely to relapse compared with LMR calves. Increases in diarrhea when feeding increased amounts of MR have been previously reported (Huber et al., 1984; Quigley et al., 2006). Contrary to the observations of BRD (where relapse rates were not influenced by age of entrance), calves that entered the study at 9 d of age and incurred diarrhea were more likely ($P = 0.03$) to experience a second case of diarrhea (20% relapse rate; 5 calves in total) than those calves entering at 16 d of age (0% relapse rate).

Once animals were in groups (n = 4), no differences existed in the incidence of BRD; however, calves that entered the study at 9 d of age had a greater ($P =$

0.007) incidence of BRD (12.5%) than those that entered at 16 d of age (0%; data not shown). In terms of relapses, no differences existed in BRD relapse rate between the 2 treatments. Contrary to the observations while calves were individually housed, the number of incidences of diarrhea while in groups did not differ between treatments (Table 3). Differences in diarrhea relapses could not be assessed because no LMR calves incurred diarrhea and none of the HMR calves that had diarrhea while in groups relapsed.

CONCLUSIONS

Before preweaning, calves on 8 L of MR grew more than those offered 6 L, but between preweaning and weaning, if milk replacer allowance was reduced from 8 or 6 to 4 L/d, calves on 6 L/d grew more than those previously offered 8 L/d, and no differences were obtained in BW at weaning and at 228 d of life. In addition, no differences in BRD (although calves on 6 L of MR per day had more relapses) or diarrhea incidence (although calves on 8 L of MR per day tended to have more relapses) should be expected. Last, based on solid feed consumption patterns seen in this study, we determined that the optimum age to reduce MR allowances and foster solid feed intake is around 45 d of age.

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