Growth performance of crossbred dairy calves fed different milk allowances using an automatic feeding system

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Abstract

The impact of feeding different levels of milk replacer via automated feeders on intake and growth was assessed in calves. Heifer calves (Holstein × Jersey; n=198; 11±4 days old) were randomly allocated to low-allowance (LA; n=67; calves were fed milk replacer at 10% of initial live weight), high-allowance (HA; n=65; calves were fed milk replacer at 20% of initial live weight), and *ad-libitum* (ADLIB; n=66; calves were given *ad libitum* access to milk replacer). Pelleted calf starter was provided *ad libitum* and daily individual intake of milk replacer and calf starter was measured via automated feeders. Calves were gradually weaned from 69±2 days over 14 days. Average daily weight gain during pre-weaning was the highest (P<0.05) for ADLIB (0.69±0.02 kg/day), followed by HA (0.61±0.02 kg/day) and LA (0.54±0.02 kg/day) calves. Calf starter intake was the lowest (P<0.05) in ADLIB calves followed by HA and LA calves. The ADLIB calves had the lowest (P<0.05) calf starter intake during the week after milk weaning but it did not affect the live weight of calves. In conclusion, provision of more milk promoted pre-weaning growth, and restricted milk feeding to trigger solid feed intake failed to match that growth advantage.

Keywords: calves; heifers; growth; automatic feeders

Introduction

Recent North American studies have demonstrated that greater pre-weaning nutrient intake and the associated increase in average daily gain of heifer calves promotes greater milk production later in life (Soberon & Van Amburgh 2014). Providing a high (20% of initial live weight) or *ad libitum* milk allowance has been shown to improve pre-weaning feed efficiency, growth and welfare in heifer calves reared for indoor systems (Jasper & Weary 2002; Rosenberger et al. 2017). However, high milk allowance can reduce liveweight gain or even result in a loss of weight in calves around weaning due to depressed solid feed intake (Khan et al. 2011).

Dairy-calf-feeding systems in New Zealand have been developed to reduce the labour and feed costs associated with calf rearing without considering the long-term effect on performance (Muir et al. 2002). Many dairy heifers in New Zealand fail to reach the appropriate live weight target at mating (44% of all heifers reared between 2012 and 2015) and pre-calving at 22 months of age (65% of all heifers reared between 2012 and 2015) (Handcock et al. 2016). Failure to reach these targets can result in late calving heifers and create a delay in getting back in calf (McNaughton & Lopdell 2012). This warrants a revisit of pre-weaning and post-weaning feeding practices that are currently being used in New Zealand for dairy replacements.

The objective of this trial was to evaluate the effects of feeding different milk replacer allowances via automatic milk feeders on the intake, growth performance, and circulating β-hydroxybutyrate (BHBA, as a proxy measure for rumen development; Quigley et al. 1991) of New Zealand crossbred (Holstein × Jersey) dairy calves during the pre-weaning and immediately post-weaning periods.

It is anticipated that calves can safely drink more milk replacer than the commonly recommended allowances (10-20% of their initial live weight; Khan et al., 2011) through the use of automatic milk feeders. Furthermore, greater ingestion and assimilation of nutrients from milk would improve pre-weaning growth rate without affecting live weight immediately after weaning.

Methods

Permission for this study was granted by the Grasslands AgResearch Animal Ethics Committee (GAEC # 14249).

Experimental design and animals

The trial was conducted in the Manawatu during the 2017 spring calving season using heifer calves born on two local farms. Calves on each farm were collected twice daily from the calving paddocks and their navels were dipped in iodine solution. All calves received 2 L of the first-milking colostrum at the time of calf collection and then until day 2 of age (2 L morning and 2 L afternoon). The calves were kept on their source farms until a minimum of four days of age before being transported to a dedicated calf-rearing facility. Experienced farm staff were responsible for the transportation of calves according to the Dairy Cattle Code of Welfare (2016).

All calves were manually fed whole milk (2 L morning and 2 L afternoon) from three to 11±4 days of age. Calves with no apparent sign of illness (e.g., diarrhoea, respiratory disease, umbilical swelling) were selected and put on the automatic milk feeders at 11±4 days of age (defined as D0).

The calves (n=198) were allocated randomly to the three treatments, balanced for source farm, date of birth and live weight. Low allowance (LA; n=67) calves were given

10% of their initial live weight (taken upon inclusion in the trial at 11±4 days of age) as milk replacer; high allowance (HA; n=65) calves were given 20% of their initial live weight as milk replacer; *ad-libitum* (ADLIB; n=66) calves were given *ad libitum* (free access) milk replacer.

The calf-rearing facility had three indoor calf pens (20.5m x 10m; minimum 2.53 m^2 per calf) each fitted with one water supply system, two automatic milk feeding stalls (CalfSMART, Palmerston North, New Zealand), and four automatic pellet-feeding stalls (CalfSMART, Palmerston North, New Zealand) which allowed individualised feeding of calves. Calves on all three treatments were allocated to each pen and calves with an approximate age difference of two weeks were kept together. All pens were bedded with wood chips and kept clean by adding more material as required. All calves had *ad libitum* access to clean drinking water and to a commercially available pelleted calf starter (Table 1, 20% crude protein pellets, SealesWinslow Limited, Tauranga, New Zealand) along with *ad libitum* access to ryegrass baleage from the third week of the experiment.

A commercially available milk replacer (Table 1; Ancalf™, NZAgbiz Ltd., Hamilton, New Zealand) was diluted in lukewarm water (150 g/L) and fed to all calves using automatic milk feeders. Calves were transitioned to milk replacer gradually by replacing whole milk with milk replacer by 33% each day during the first three days on the automatic milk feeders. All calves had an allowance of 4 L/day during the transition from whole milk to milk replacer and then the amount of milk replacer was adjusted over the next four days to achieve their respective daily milk replacer allowance based on their treatment group. Once the transition to the full treatment allowance was completed (by D7), the automatic milk feeder was programmed to allow calves a maximum consumption of 4 L milk replacer at a single feed/visit with a 2-hour wait time between consecutive feedings to avoid over-feeding.

Weaning from milk replacer began at D69±2, and milk replacer was gradually reduced over 14 days by linearly reducing the volume of milk replacer based on each calves mean consumption in the three days prior to the start of weaning.

All calves were vaccinated (Ultravac 7in1, Zoetis, Auckland, New Zealand) between 4-8 weeks of age, and all calves received antibiotics (Alamycin LA300, Norbrook, Auckland, New Zealand) as prevention for pneumonia. All calves were disbudded at 4-8 weeks of age using a hot iron under local anaesthesia by a certified contractor.

Measurements and sampling

Individual calf intakes (milk replacer, L/calf/day and calf starter, kg/calf/day) were recorded by the automatic feeders using radio-frequency identification ear-tags. Feeders (milk replacer and calf starter) were calibrated before the start of the experiment and their functions were monitored daily for accuracy by CalfSMART staff throughout the trial. Water and baleage intake was not measured. Live weights of all calves were recorded using a digital weighscale monitor (Gallagher TW1 Data Monitor, Hamilton New Zealand) attached to a double load-bar scale (Technipharm, Rotorua, New Zealand). A weight measurement was taken at the start of the experiment (D0) and at the conclusion of weaning (D83±2), and average daily gain (ADG) for the pre-weaning period calculated from these two measurements. A further weight measurement was taken at D91±2 and used together with the weaning measurement to calculate post-weaning ADG.

Samples of milk replacer and calf starter were taken at regular intervals over the course of the trial period (n=5 each of milk replacer and calf starter) and pooled (n=2 of each) for analysis. Composition of milk replacer was determined following the procedures of AOAC (1990; Nutrition Laboratory, Massey University, Palmerston North, New Zealand). Composition of calf starter was determined using conventional wet-chemistry methods (RJ Hill Laboratories, Hamilton, New Zealand). Metabolisable energy in calf starter was determined using AFRC (1993) and Lincoln University standard formulae and in milk replacer according to the equations given by NRC (2001).

Blood samples were collected from the jugular vein of calves (n=192) at D86±2. A 10-ml blood sample was collected in evacuated tubes (Vacutainer containing EDTA; Becton-Dickinson, Wellington, New Zealand) from each calf to harvest plasma. The blood samples were centrifuged (20 min at 1300 *g*) and three sub-samples of plasma were archived at about -80°C until analysis. Analysis of BHBA was carried out with an enzyme kinetic assay (Randox Laboratories Ltd, United Kingdom).

Table 1 Nutritional composition of pelleted calf starter and milk replacer calculated from pooled samples (n=2 each of calf starter and milk replacer).

Nutritive component, % DM[1]	Calf starter[2]	Milk Replacer[3]
Dry matter, %	87.15	96.1
Metabolisable energy, MJ/kgDM[4]	13.75	20.59
Crude protein	20.4	24.95
Lactose	-	39.5
Acid detergent fibre	4.1	-
Neutral detergent fibre	9.6	-
Ash	7.5	6.35
Organic matter	92.5	-
Soluble sugars	5.55	-
Starch	40.5	-
Crude fat	2.05	21
Non-structural carbohydrate	60.4	-
Organic matter digestibility *in-vivo*	93.05	-

DM=dry matter; MJ=megajoules. [1]except where otherwise stated. [2]20% pellets, SealesWinslow Ltd., Tauranga, New Zealand. [3]Ancalf™, NZAgbiz Ltd., Hamilton, New Zealand. [4]Metabolisable energy in calf-starter was determined using AFRC (1993) and Lincoln University standard formulae and in milk replacer according to the equations given in NRC (2001).

Statistical analysis

The data showed a different pattern (e.g., mean, variance and trend) between the pre-and post-weaning period, hence a mixed-effects model with random effect of farm source, and fixed effects of length of period (covariate) and treatment were used to analyse the pre- and post-weaning data separately (R Core Team, 2016). Milk replacer intake and calf starter intake data was log-transformed to meet the model assumption of normality, and one outlier was removed for the calf starter intake data. For ADG, initial live weight and age at inclusion on trial were added in the above-mentioned model as covariates, and ADG in the post-weaning period that exceeded ±1.5 kg/day were removed, as these were deemed to be measurement errors. Predicted means for the significant terms (P<0.05) in the model were produced with a multiple comparison, and the P values of multiple comparison were adjusted by the "Benjamini–Hochberg" method. Predicted means were calculated in order to remove any bias that could be caused when analysing and comparing data where there were a different number of data points. For BHBA results (the data was left-censored at a value of 0.10 mmol/L due to the assays lower limit), a censored regression model with model terms of age of calf at blood sampling, days of experiment at blood sampling, days after weaning at blood sampling and treatment was performed for checking the effect of treatment. The analysis was performed using packages "lme4", "predictmean" and "censReg" in R 3.4.1.

Results

Calf starter intake was inversely associated with milk-replacer allowance, such that LA calves consumed the greatest amount of calf starter and ADLIB calves the least (P<0.05). Average daily dry matter intake (DMI) (milk replacer plus calf starter) over the pre-weaning period was greatest (P<0.05) in ADLIB and lowest in LA calves (Table 2). Daily calf-starter DMI as a percentage of total daily DMI during the milk feeding period was 9.8% in ADLIB, 24.4% in HA and 44.6% in LA.

The maximum milk replacer intake of ADLIB calves was 12.8 L (1.92 kg milk replacer/day or 34.4% of initial live weight/day), with intake plateauing after 50 days on trial. There was no difference in calf-starter intake between HA and LA calves in the post-weaning period, but it was lower (P<0.05) in ADLIB calves (Table 2).

Calves on ADLIB had the greatest ADG during pre-weaning and LA calves the lowest (P<0.05). In the post-weaning stage there was no difference in ADG between treatments (P>0.05). Overall ADG (D0-91) was highest (P<0.05) in ADLIB and lowest in LA calves (Table 2).

Mean levels of BHBA around the conclusion of weaning (mmol/litre, ± SEM) were 0.24±0.02 for ADLIB, 0.26±0.02 for HA and 0.29±0.03 for LA calves. There was no difference between treatments (P>0.05).

Table 2 Predicted means of the average daily intake of milk replacer and pelleted calf starter, average daily dry matter intake (milk replacer and calf starter) and average daily gain of calves during the pre- and post-weaning stages, and overall.

	Treatment			
Parameter	LA	HA	ADLIB	SED
Pre-weaning (D0-83)				
Live weight D0	38.21	37.61	37.59	2.25
Milk replacer intake (litres/day)	3.62[a]	6.34[b]	8.97[c]	0.02
Milk replacer (kg DMI/ day)	0.51[a]	0.9[b]	1.26[c]	0.02
Calf starter (kg DMI/day)	0.39[c]	0.24[b]	0.14[a]	0.08
Total intake (kg DMI/ day)	0.88[a]	1.14[b]	1.38[c]	0.03
ADG (kg/day)	0.54[a]	0.61[b]	0.69[c]	0.02
Post-weaning (D84-91)				
Live weight D83	84.4[a]	88.12[a]	96.88[b]	2.25
Calf starter (kg DMI/day)	1.01[b]	1.03[b]	0.84[a]	0.08
ADG (kg/day)	0.46	0.33	0.29	0.35
Overall (D0-91)				
Live weight D91	88.17[a]	91.82[a]	98.54[b]	2.25
Calf starter (kg DMI/day)	0.47[c]	0.35[b]	0.22[a]	0.02
Total intake (kg DMI/ day)	0.89[a]	1.13[b]	1.34[c]	0.03
ADG (kg/day)	0.56[a]	0.62[b]	0.68[c]	0.03

DMI=dry matter intake; ADG=average daily gain; SED=standard error of differences; D=days of trial; Total intake=milk replacer + calf starter; [a,b,c]values within each item with different superscripts are significantly different (P<0.05).

Discussion

Overall, calves consumed milk according to their permitted allowance. In agreement with previous work (Khan et al. 2011), the calves on ADLIB consumed on average 2.45 and 1.41 times more milk than LA and HA calves respectively. The intake of calves on ADLIB clearly demonstrate that crossbred heifer calves reared artificially as dairy replacements can safely consume greater amounts of milk than is generally being recommended and used (8-20% of the initial live weight of the calf) for indoor (Khan et al. 2011) and pastoral systems (Muir et al. 2002). A large variation in milk replacer intakes amongst the calves reared on milk replacer *ad libitum* compared to the other treatments was observed, reflecting the difference between individual calves in their desire or ability to drink and suck. This could be caused by variation in their initial live weights, genetics, training of calves to feeders, age of the calves, and competition on the feeder (Rosenberg et al. 2017). In the present study, calves in each pen were born within two weeks of each other, and calves had access to the two automatic feeders in each pen for 24 hours daily, therefore, group competition may not have been a factor affecting the variation in milk intake. Initial differences in the live weight of the outbred genetic group typical to New Zealand dairy herds (Lopez-Villalobos et al. 2000) could be considered one of the major factors in dictating the amount of nutrients needed and consumed from milk by the calf to support liveweight gain. Therefore, automatic milk feeding systems that can tailor individual milk allowance could provide a potentially beneficial opportunity to feed group-housed calves individually according to their requirements.

Calf-starter intake increased with decreasing level of milk allowance, as calves on restricted milk-replacer allowance attempted to increase their consumption of calf starter to meet nutrient demands for growth. This increased calf-starter intake by LA calves was not enough to achieve similar DMI to HA calves, and HA calves also failed to achieve total DMI equivalent to ADLIB calves. Neonatal calves grow in their capacity for solid feed intake as they get older and rumen development is considered a pre-requisite for the initiation of solid feed consumption (Khan et al. 2016). However, for the first few weeks of life, intake of calf starter is negligible (Miller-Cushon et al. 2013) and capacity for rapid growth is high (Jasper & Weary 2002). If milk intake is limiting during this period, as is the case with LA calves, then the calves will be unable to compensate for the lower nutrient supply from milk by increasing solid feed intake. The lower calf-starter intake of ADLIB calves after weaning was likely due to the more-drastic change in the diet of ADLIB during weaning compared to HA or LA calves (Khan et al. 2016). A similiar experiment by Jasper and Weary (2002) found no difference in calf-starter intake after weaning between calves fed *ad libitum* and restricted milk, though the post-weaning period in their study was 20 days long (43-63 days). It is likely that calf-starter intake in the ADLIB calves would increase over time after weaning, causing the difference in this trial to become non-significant. Calf-starter intake for all treatments after weaning was lower than reported in similar studies (Terré et al. 2007; Jasper & Weary 2002), which could be ascribed to differences in size and genetics of the calves, length of the pre-weaning period, and duration of post-weaning measurements. Calf-starter intake in the pre-weaning period still makes up a reasonable portion of the diet (9.8%) in the calves given *ad libitum* access to milk, illustrating their desire for solid food even when nutrient availability from milk is unlimited (Khan et al. 2011).

The results of this study indicate, that to avoid limiting pre-weaning growth rates in young calves, a high milk allowance is needed. Growth rates for ADLIB calves were lower than reported in some North American literature (Miller-Cushon et al. 2013; Jasper & Weary 2002) in which calves generally had pre-weaning growth rates of 0.8-1.1 kg/day. Breed difference may be a contributing factor to this, as the calves used in this trial would typically have a lower mature live weight than that of North American Holstein-Friesans, and therefore, have lower potential growth rates (Berry et al. 2005).

Admittedly, the post-weaning period in this study was short and the variation amongst calves within treatments was large for post-weaning ADG. However, the lack of difference in ADG post-weaning agrees with other studies (Jasper & Weary 2002; Rosenberger et al. 2017) where calves were fed *ad libitum* versus restricted milk allowance.

Calf rumen development is stimulated by the intake of solid feed and the ensuing production of volatile fatty acids (VFA; Khan et al. 2011). Circulating BHBA levels can be used as an indicator of rumen development and the ability of the animal to absorb VFA (Quigley et al. 1991). There was no significant difference in BHBA levels around weaning, indicating that metabolic development of the rumen wall and absorption of VFA was similar between the treatments.

In conclusion, this study indicates that crossbred calves can ingest a greater amount of milk than is generally recommended. Despite reducing the calf-starter intake, greater nutrient intake from milk promoted greater pre-weaning ADG in calves. No significant difference was seen in growth rates during and immediately after weaning. Further research is warranted to determine the effects of pre-weaning growth on the long-term performance of dairy heifers in pastoral systems.

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