The effect of milk replacers containing a higher carbohydrate content on the growth performance of Holstein bull calves.

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1.1 Abstract

This study examines the effects of two milk replacers, a standard commercial calf milk replacer (CMR) and a high starch calf milk replacer (SCMR), on growth performance and cost-effectiveness in pre-ruminant Holstein bull calves. Sixteen calves, aged between 3 to 4 days, were randomly assigned to the two treatment groups and observed over a 77-day period, which included a gradual transition to the high carbohydrate diet. Proximate analysis confirmed that both formulations maintained iso-energy and iso-protein levels, while the SCMR exhibited a higher carbohydrate content.

Growth performance metrics—average daily gain (ADG), dry matter intake (DMI), and feed conversion ratio (FCR)—were evaluated using one-way ANOVA. The results indicated no significant differences between the two treatments across all growth metrics ($p > 0.05$). Nonetheless, the SCMR demonstrated a significant cost advantage, reducing total feed costs and improving financial returns compared to the CMR ($p < 0.05$).

The findings suggest that while both milk replacers supported comparable growth rates, the SCMR offers a more economical alternative, thereby enhancing the financial viability of calf rearing. Future research should investigate the long-term effects of high carbohydrate diets on rumen development and enzyme activity in pre-ruminants.

1.2 Introduction

At birth, a calf's rumen is undeveloped, making microbial fermentation insignificant. Young calves, termed pre-ruminants, rely on enzymatic digestion in the abomasum and duodenum. Milk bypasses the rumen via the oesophageal groove reflex. Different milk replacers affect growth rates and diarrhoea incidence, influenced by rearing conditions. The study focused on carbohydrates using a high-carb milk replacer.

Significant carbohydrate digestion starts in the small intestine, not the abomasum. Lactose, the primary milk carbohydrate, must be hydrolysed by β-galactosidase, which peaks shortly after birth and declines with age. Pre-ruminants can easily utilize glucose, galactose, and lactose but have limited ability to digest maltose, starches, and cannot digest sucrose.

Including cooked maize in milk replacers increases starch levels, broken down into maltotriose and maltose. Maltase and isomaltase activity, crucial for starch digestion, reach adult levels within four weeks. Various factors determine starch digestion rates, while excessive starch or sugar intake can cause diarrhoea.

High carbohydrate milk replacers require optimal maltase and isomaltase levels. By two weeks, enzyme activity reaches half of that in adults, making high-starch milk replacers suitable for young calves.

1.3 Materials and methods (Experimental design)

Prior to this study, ethical clearance was obtained from the UFS Animal Research Ethics Committee for all trial-related practices. The project number is UFS-AED2023/0051. the CMR and the SCMR were formulated to achieve iso-energy and iso-protein levels for both formulations. This was verified by collecting random samples of the different milk replacers during the trial and analyzing them.

A calf rearing trial with different milk replacers as treatments was conducted. This took place at the calf rearing unit of Livestock Wellness in George, which provided the different milk replacers for the trial in collaboration with Nandrea Health Products. The experimental groups for the trial were as follows:

The first group was fed the CMR, a commercial milk replacer that served as the standard. The second group was fed the SCMR, a high carbohydrate milk replacer. During the trial, a regime of three feedings of 2 liters of milk replacer per day was used. On day one of the trial, the calves were fed 1 liter per feeding, and this was increased in steps of 200 ml per feeding per day until 2 liters per feeding was reached. At the end of the trial, the milk replacer intake was gradually decreased to 1 liter and two feedings per day. After weaning, the calves were kept in the unit for a further two weeks and were fed starter meal. Any milk replacer refusals were noted, and total milk intake was compounded on a weekly basis.

During the calf rearing trial, a standard commercial starter meal was used, and the calves had ad lib access to it throughout the trial. Weekly starter intake was determined by weighing feed offered and refusals. The calves were marked and numbered with different color tags and randomly allocated to the treatment groups. Sixteen Holstein bull calves were sourced from a local farmer and used in the trial. These calves received colostrum after birth and entered the trial at an age of between three and four days.

Table 1.1 The experimental design of the trail, with a total of 16 calves (N=16) allocated to two different treatments (n=8).

	Standard carbohydrate levels	**High starch milk replacer (HCMR)**
Commercial milk replacer	n=8 CMR	n=8 SCMR
		N=16

The trial began with an experimental group of 16 calves, which were divided into two groups of eight calves each during a transition phase from days 11 to 13 for the high starch milk replacers. This transition phase was implemented to gradually switch the group to the high starch milk replacer and reduce the incidence of diarrhoea due to dietary changes.

By the time calves are 11 days old, the activity levels of starch digestive enzymes such as amylase, maltase, and isomaltase have increased sufficiently to allow the successful introduction of high starch milk replacers (Miyashige & Yahat, 1980; Hamon, 1993). Hamon (1993) further indicates that amylase activity can be nutritionally manipulated. The transition involved starting with the inclusion of 25% starch milk replacer on day 11 and increasing it in increments of 25%, reaching 100% by day 14.

A standard vaccination program was followed, and calves were weighed weekly starting on day 0. Table 1.2 presents the prices per kilogram of milk replacer (February 2024), along with the calculated prices per kilogram of the starter meal. Additionally, it includes the prices per kilogram for the calves if they had been sold at the end of the trial, according to the RPO (Red Meat Producers Organisation, 01/03/2024), as these were used for the calculation of some parameters.

Tabel 1.2 Prices used for the calculation of parameters used in the cost benefit analysis.

	Prices: R/Kg & R/L
CMR	58,25
SCMR	47,95
Starter meal	7,53

The following section presents the cost-benefit analysis, conducted to evaluate the financial viability and advantages of the various treatments.

1.4 Results and Discussion

This trial compares the CMR and the SCMR, focusing on their carbohydrate levels. Differences in reported parameters are directly related to carbohydrate content. Table 1.3 provides abbreviations for simplicity.

Tabel 1.3 Abbreviation to simplify the explanation of results.

Milk replacers	Carbohydrates
CMR	Standard Carbohydrate (SC)
SCMR	High Carbohydrate (HC)

3.4.1 Proximate analysis

The milk replacers were formulated to be iso-energety and iso-protein across different formulations. A proximate analysis was conducted on both the milk replacers and the starter meal (SM) used in the trial. Fat content was determined using the Roese-Gottlieb method. Pooled samples from various batches throughout the trial were analyzed, as shown in Table 1.4. A detailed proximate analysis is available in the appendix.

Table 1.4 The results of a proximate analysis performed on the milk replacers and starter meal.

Milk replacer and Starter meal	N (%)	CP (%)	Crude fat (%)	ME (MJ/kg)
CMR	3,33	20,78	15,92	12,85
SCMR	3,12	19,50	12,14	12,63
SM	2,47	15,44	3,17	10,57

Both milk replacers had similar metabolizable energy due to their iso-energy, iso-protein formulation and the higher carbohydrate content in the SCMR.

3.4.2 Time

The trail data was grouped by different phases, shown in Figure 1.1. During Phase 1 (P1), calves were fed milk replacer from day 1 to day 63, when they were weaned. Phase 2 (P2) covered the two-week post-weaning observation from day 64 to day 77 to check for wean shock. The total phase (TP) spanned from day 0 to day 77. Calves were weighed weekly, using corresponding cumulative intake and weight for data analysis.

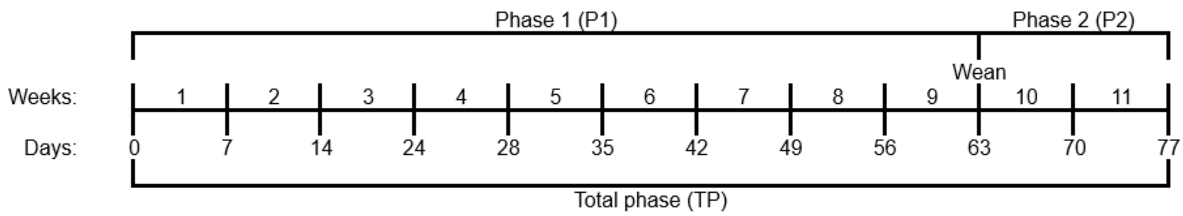

Figure 1.1 A line diagram of the time periods used in the trail. The direct influence of the different milk replacers was investigated during P1. Transfer effects such as wean shock were investigated during P2 and TP was used to determine direct and transfer effects.

Table 1.5 states the null and alternative hypotheses for this One-way ANOVA. Since both milk replacers were designed to be iso-energy and iso-protein, we can refine the hypotheses by focusing on carbohydrate levels. The p-value interpretation is clarified to help with data analysis.

Tabel 1.5 The hypotheses tested with the One-way ANOVA analysis of the data for the growth performance parameters.

Null and alternative hypotheses	Carbohydrate main effect	P-value interpretation	
H_0: $\mu_{CMR} = \mu_{SCMR}$ H_A: $\mu_{CMR} \neq \mu_{SCMR}$	H_0: $\mu_{SC} = \mu_{HC}$ H_A: $\mu_{SC} \neq \mu_{HC}$	p-value ≤ 0.05 {Reject H_0}	$\mu_{SC} \neq \mu_{HC}$
		p-value > 0.05 {Accept H_0}	$\mu_{SC} = \mu_{HC}$

1.4.3 Results

Table 1.6 presents the comparison of the CMR and the SCMR regarding various growth performance parameters.

Table 1.6 Summarised comparison of the performance data of the CMR and the SCMR for the different phases of the trial.

Phase	Parameter	Mean ± Standard deviation		P-value
		CMR	SCMR	
TP	**Initial weight**	39,938 ± 2,608	40,025 ± 2,733	0,899
	Final weight	96,938 ±12,073	97,525 ± 8,403	0,853
	DMI (MR&SM)	142,541 ± 21,241	148,046 ± 13,214	0,316
	DMI (MR)	51,997 ± 0,967	51,855 ± 0,897	0,576
	DMI (SM)	90,544 ± 21,203	96,191 ± 13,238	0,303
	ADG	0,740 ± 0,160	0,747 ± 0,120	0,878
	(DMI/BW) %	0,027 ± 0,003	0,028 ± 0,002	0,122
	FCR	2,545 ± 0,301	2,615 ± 0,347	0,371
P1	**Initial weight**	39,938 ± 2,608	40,025 ± 2,733	0,899
	Final weight	78,925 ± 9,414	78,875 ± 5,749	0,984
	DMI (MR&SM)	96,419 ± 14,304	100,175 ± 9,407	0,310
	DMI (MR)	51,997 ± 0,967	51,855 ± 0,897	0,576
	DMI (SM)	44,422 ± 14,223	48,320 ± 9,441	0,288
	ADG	0,619 ± 0,147	0,617 ± 0,093	0,955
	(DMI/BW) %	0,026 ± 0,003	0,027 ± 0,002	0,101
	FCR	2,535 ± 0,332	2,610 ± 0,312	0,383
P2	**Initial weight**	78,925 ± 9,414	78,875 ±5,749	0,984
	Final weight	96,938 ± 12,073	97,525 ± 8,403	0,853
	DMI (SM)	46,122 ± 7,960	47,871 ± 5,477	0,398
	ADG	1,287 ± 0,283	1,332 ± 0,273	0,539
	(DMI/BW) %	0,037 ± 0,004	0,039 ± 0,004	0,182
	FCR	2,611 ± 0,415	2,633 ± 0,480	0,840

p-Values >0.05 suggest that H_0 can be accepted, implying $\mu_{CMR} = \mu_{SCMR}$ for all growth performance parameters in every phase. Note that P2 lasted only 2 weeks, and a longer period might have shown significant differences in growth rate. The study found no significant differences between the growth performances of the two milk replacers. Although not significant, calves on the SCMR exhibited lower wean shock. Future research should consider a longer post-weaning observation period. Given the similar growth performances, the cost-benefit analysis was also conducted, as shown in Table 1.7.

Table 1.7 The mean, standard deviation and p-value corresponding to the parameter both milk replacers treatment over all phases.

Phase	Parameter	Mean ± Standard deviation		P-value
		CMR	SCMR	
TP	**Cost (MR&SM)**	3497,011 ± 248,624	3317,697 ± 107,900	0,001
	Cost (MR)	2815,213 ± 235,441	2593,381 ± 48,937	0,000
	Cost (SM)	681,798 ± 159,660	724,316 ± 99,684	0,303
	ADC	45,416 ± 3,229	43,087 ± 1,401	0,001
	Cost/WD	63,717 ± 12,758	58,832 ± 8,220	0,130
	Income	-346,598 ± 370,845	-146,069 ± 236,431	0,025
P1	**Cost (MR&SM)**	3149,714 ± 232,698	2957,227 ± 82,672	0,000
	Cost (MR)	2815,213 ± 235,441	2593,381 ± 48,937	0,000
	Cost (SM)	334,500 ± 107,100	363,847 ± 71,093	0,288
	ADC	49,995 ± 3,694	46,940 ± 1,312	0,000
	Cost/WD	85,118 ± 21,667	77,430 ± 10,092	0,163
	Income	-649,732 ± 315,332	-459,051 ± 148,075	0,010
P2	**Cost (SM)**	347,298 ± 59,943	360,470 ± 41,239	0,398
	ADC	24,807 ± 4,282	25,748 ± 2,946	0,398
	Cost/WD	19,660 ± 3,121	19,826 ± 3,611	0,840

p-Values <0.05 are highlighted, indicating H_0 is rejected. This means $\mu_{CMR} \neq \mu_{SCMR}$ for that parameter.

Table 1.7 shows that the SCMR, with similar growth performance to the CMR, was cheaper.

1.4.4 Discussion

Pre-ruminants can utilize glucose, galactose, and lactose but have limited ability to use maltose and starches, and cannot use sucrose (Dollar and Porter, 1957; Walker, 1959; Estévez et al., 2014). Maltase activity increases in calves and reaches half the adult level by two weeks of age (Krehbiel et al., 1984; Le Huerou et al., 1992).

High starch content in milk replacers can boost starter meal intake, aiding rumen development. Maltase activity appears responsive to starch exposure, improving enzyme utilization. Enhanced digestion in the abomasum promotes early rumen development, warranting further investigation.

1.5 Conclusion

In conclusion, the CMR and the SCMR showed no significant differences in growth performance parameters. However, using the SCMR provided a cost benefit. Based on this data, using the SCMR instead of a more expensive commercial milk replacer can be financially advantageous when rearing calves.

1.6 References

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