

# Growth Response and Feed Cost Efficiency of Early-Weaned Crossbred (HF × K) Calves under Different Milk Feeding Regimens

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## ABSTRACT

This study evaluated the impact of high milk feeding on the recurring cost of 25 early-weaned crossbred (HF×K) calves for 182 days. Newborn calves (average birth weight 30.71 kg) were randomly divided into five treatment groups with two males and three females in each. The birth weight of calves under different treatment groups was statistically nonsignificant. All calves received colostrum for the first 3 days, followed by 4 litters of fresh milk daily for the next two weeks. Thereafter, milk quantities varied among treatment groups, totalling 252, 329, 353.5, 378, and 420.5 litters in T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub>, T<sub>4</sub> & T<sub>5</sub> groups, respectively, over first 63 days of life. The milk feeding was in step up from 15 days @ 0.5 lit /week till 49<sup>th</sup> day and then step-down manner till 63<sup>rd</sup> day in T<sub>2</sub> to T<sub>5</sub> groups. Total Mixed Ration (TMR) was offered *ad libitum* to all calves during 15-90 (C:R; 75:25) and 91-182 (65:35) days of age, respectively. The calves were weighed weekly using an electronic weighing balance prior to milk feeding. Feeding cost under different treatments was estimated based on daily feed intake multiplied by the unit cost of the TMR. Feed cost per kg body weight gain and feed cost per day were calculated from the total feed expenditure incurred. The average feed cost per kg gain was ₹ 466.20 and ₹ 164.98 during pre-weaning and post-weaning, respectively, and ₹ 239.65 for overall period. The lowest overall feed cost per kg gain was recorded in T<sub>1</sub>, followed by T<sub>3</sub>, T<sub>2</sub>, T<sub>4</sub>, and T<sub>5</sub>, but statistically it was at par, though the average daily feed cost was significantly ( $p < 0.01$ ) lower (₹ 167.19) with T<sub>1</sub> than other treatments. Thus, the pre-weaned crossbred calves can be reared on either T<sub>3</sub> or T<sub>4</sub> milk feeding protocol to maximize their growth rate.

**Key words:** Body weight gain, Crossbred calves, Feed cost, High milk feeding, Water intake.

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## INTRODUCTION

The young dairy calves represent the future replacement stock (Fischer *et al.*, 2019) at a commercial dairy farm. Improved growth rate in heifer calves enables them to attain the target breeding weight at a younger age, which can shorten the age at first calving and ultimately lower the overall cost of replacement heifer rearing (Davis-Rincker *et al.*, 2011). Feed cost represents a major component of total expenditure in dairy calf rearing, with milk and concentrate-based rations contributing substantially to overall rearing costs. Early weaning and restricted milk feeding plans have been widely used as strategies to cut the feeding costs of rearing young calves. This can be accomplished by promoting early consumption of dry feeds, which stimulates rumen development and reduces dependence on milk or milk replacer while maintaining adequate growth and health (Khan *et al.*, 2011). Different milk feeding regimes influence growth performance of calves during pre- and post-weaning phases as well as the economic efficiency of rearing systems. Higher milk allowance has been reported to enhance early growth rate and health status of calves; however, it may considerably increase rearing costs, raising

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concerns regarding the economic sustainability of such feeding strategies (Drackley, 2008).

The controlled milk feeding led to higher drinking water, water intake was increased after weaning, and the water intake and the amount of starter that was consumed were correlated (Kertz *et al.*, 1984). Total mixed rations (TMR) with varying forage-to-concentrate ratios further affect post-weaning growth and feeding costs. Assessment of total feed expenditure, feed cost per unit body weight gain, and daily feed cost provides a comprehensive understanding of the biological and economic efficiency of calf feeding protocols. Previous studies have shown that calves fed higher milk allowances incur greater feed cost and feed cost per kg gain compared to restricted milk-fed calves, although overall growth advantages may not always be proportional to the increased expenditure (Uys *et al.*, 2011). Cheema *et al.* (2016) stated that for affordable livestock production high-milk feeding coupled with early weaning can be a better alternative because it is more cost-effective during the pre-weaning period. Therefore, the present study was undertaken to evaluate the effect of different milk feeding regimes on total feed cost, body weight gain, feed cost per kg gain, and daily feed cost in dairy calves, to identify an economically efficient milk feeding strategy that supports optimal growth performance.

## MATERIALS AND METHODS

The study was conducted at Livestock Research Station, Kamdhenu University, Anand, Gujarat (India), after IAEC approval (No. 362/LRS/2022) for 182 days (26 weeks). Total of 25 newborn crossbred calves (75% Holstein Friesian × 25% Kankrej; average birth weight 30.71 kg) were grouped into five equal treatments, with statistically identical weight, comprising two male and three female calves in each. All calves were fed colostrum (4 L/day) for the first 3 days and milk (4 L/day) from day 4 to day 14. Thereafter, from day 15 to day 63, milk was offered according to Table 1 in a step-up and step-down manner. The calves were fed a total mixed ration-TMR1 (75% Concentrate, 15% green Hybrid Napier, and 10% dry Jowar hay) and TMR-2 (65% Concentrate, 15% green Hybrid Napier, and 20% dry Jowar hay) *ad libitum* during 15-90 days and 91-182 days, respectively.

The feeding cost under different treatments was calculated using daily feed intake and prevailing unit prices of feed ingredients. Milk price was based on cooperative rates of AMUL, concentrate price on average AMUL Dairy market prices, and fodder prices on University selling rates at Anand are presented in Table 2. Actual prices were used to estimate total feeding cost and feed cost per kg body weight gain.

The calves were weighed weekly using an electronic weighing balance before milk feeding. Body weight gain was calculated from the weekly body weight records. Water intake was determined by subtracting the residual water from the quantity offered and was recorded weekly. The cost of

feeding under different treatments was calculated based on daily feed consumption records multiplied by the respective unit price of the TMR. Feed cost per kg body weight gain and feed cost per day were calculated using the total feed expenditure incurred for rearing calves under each individual treatment.

**Table 1:** Feeding schedule for experimental calves

Age (days)	Milk feeding regimes (Lit/day)				
	T1	T2	T3	T4	T5
15-21	4.0	4.5	5.0	5.5	6.0
22-28	4.0	5.0	5.5	6.0	6.5
29-35	4.0	5.5	6.0	6.5	7.0
36-42	4.0	6.0	6.5	7.0	7.5
43-49	4.0	6.5	7.0	7.5	8.0
50-56	4.0	6.0	6.5	7.0	7.5
57-63	4.0	5.5	6.0	6.5	7.0
<b>Total (L)</b>	<b>252.0</b>	<b>329.0</b>	<b>353.5</b>	<b>378.0</b>	<b>402.5</b>
15 to 90	TMR-1 (C:R, 75:25) <i>ad libitum</i>				
91-182	TMR-2 (C:R, 65:35) <i>ad libitum</i>				

**Table 2:** Cost of ingredients and TMR used in experiment

Sr. No.	Particulars	Price (₹/kg)
1	Milk	36.00
2	Concentrate	31.51
3	Dry fodder (Jowar hay)	6.00
4	Green fodder (H. Napier)	2.00
5	TMR 1 (75:25)	24.53
6	TMR 2 (65:35)	21.98

The data (Mean ± SE) obtained employing a complete randomized design was analyzed by using online OPSTAT Software developed by O. P. Sheoran, Professor of Statistics, COBS&H, CCS, HAU, Hisar, Haryana, India (Snedecor and Cochran, 2014).

## RESULTS AND DISCUSSION

### Weekly Body Weight (kg)

The weekly body weight data indicated a consistent and progressive increase across all treatments throughout the experimental period (Table 3). The initial birth weights were comparable among groups, suggesting uniform distribution of calves at the start of the trial. The pre-weaning mean body weight differed significantly ( $p < 0.05$ ) among treatments, with T<sub>4</sub> (48.60 ± 1.93 kg) recording the highest value, followed by T<sub>2</sub>, T<sub>3</sub>, and T<sub>5</sub>, which remained statistically similar but significantly higher than T<sub>1</sub>. The superior performance of T<sub>4</sub> during the milk-feeding phase suggests that the respective feeding regimen supported better early growth, likely through improved nutrient intake and metabolic efficiency. The present finding is in agreement with Jasper and Weary (2002) and Alimirzaei *et al.* (2020), who also reported that pre-weaned calves getting high milk feeding gained more weight. The post-weaning mean body weight was significantly



( $p < 0.05$ ) highest in  $T_4$ , followed by  $T_3$  and  $T_2$ , whereas  $T_1$  recorded the lowest value. The sustained advantage of  $T_4$  beyond weaning indicates that early nutritional management had a carryover effect on later growth performance. The overall mean body weight further confirmed the superiority of  $T_4$ , which was significantly ( $p < 0.05$ ) higher than all other treatments. These findings demonstrate that the feeding strategy adopted in  $T_4$  optimized growth both before and after weaning, highlighting the importance of balanced milk and solid feed management in early-weaned crossbred calves. Arens *et al.* (2023) and Welk *et al.* (2023) reported that during the pre-weaning phase, high milk allowances had

a good or desired influence on growth of calves, whereas De-Passille *et al.* (2011) disagree with present finding.

#### Feed Intake (DM basis, g/day)

The treatment-wise feed intake (DM basis) revealed a clear shift in nutrient consumption pattern with increasing milk allowance (Table 4). Milk dry matter intake increased progressively from  $T_1$  (504.00 g/day) to  $T_5$  (805.00 g/day), with an overall mean of 686.00 g/day, indicating strict adherence to the designed feeding regimes. TMR-1 (75:25) intake differed significantly ( $p < 0.05$ ) among treatments. Calves under  $T_1$  recorded the highest intake (320.20 g/day), which

**Table 3:** Weekly body weight (kg) of the early-weaned crossbred calves during experiment (Mean  $\pm$  SE)

Weekly body weight (kg)	Milk feeding protocols / Treatments				
	$T_1$	$T_2$	$T_3$	$T_4$	$T_5$
Birth wt.	28.64 $\pm$ 2.52	32.76 $\pm$ 1.48	29.04 $\pm$ 1.83	32.52 $\pm$ 1.58	30.60 $\pm$ 0.69
P1	30.16 $\pm$ 2.48	33.66 $\pm$ 1.28	31.12 $\pm$ 1.20	33.60 $\pm$ 1.62	31.26 $\pm$ 0.61
P2	32.08 $\pm$ 2.42	35.26 $\pm$ 1.14	32.82 $\pm$ 1.48	35.04 $\pm$ 1.45	32.84 $\pm$ 0.77
P3	34.34 $\pm$ 2.22	37.76 $\pm$ 0.95	35.60 $\pm$ 1.90	38.84 $\pm$ 1.42	36.24 $\pm$ 1.14
P4	36.92 $\pm$ 2.15	40.68 $\pm$ 1.04	38.92 $\pm$ 1.82	44.36 $\pm$ 1.22	41.00 $\pm$ 1.31
P5	40.36 $\pm$ 2.28	43.96 $\pm$ 1.58	44.04 $\pm$ 2.00	49.72 $\pm$ 1.16	45.40 $\pm$ 1.33
P6	43.04 $\pm$ 2.39	48.04 $\pm$ 2.19	48.60 $\pm$ 1.73	54.68 $\pm$ 1.01	50.62 $\pm$ 1.76
P7	47.32 $\pm$ 2.54	52.28 $\pm$ 2.91	54.80 $\pm$ 1.19	60.04 $\pm$ 0.87	55.48 $\pm$ 2.23
P8	51.92 $\pm$ 2.88	57.44 $\pm$ 3.45	60.36 $\pm$ 1.15	65.84 $\pm$ 0.73	60.64 $\pm$ 2.29
P9	55.70 $\pm$ 2.78	62.76 $\pm$ 3.88	65.68 $\pm$ 1.72	71.36 $\pm$ 1.01	66.12 $\pm$ 2.38
<b>Pre-weaning Mean</b>	<b>40.05<sup>a</sup> <math>\pm</math> 1.45</b>	<b>44.46<sup>b</sup> <math>\pm</math> 1.55</b>	<b>44.10<sup>b</sup> <math>\pm</math> 1.80</b>	<b>48.60<sup>c</sup> <math>\pm</math> 1.93</b>	<b>45.02<sup>b</sup> <math>\pm</math> 1.79</b>
P10	59.12 $\pm$ 3.34	66.24 $\pm$ 3.79	68.86 $\pm$ 1.91	74.88 $\pm$ 1.20	69.00 $\pm$ 2.47
P11	63.24 $\pm$ 3.57	70.52 $\pm$ 4.80	72.28 $\pm$ 1.91	79.88 $\pm$ 1.76	72.04 $\pm$ 2.80
P12	68.20 $\pm$ 4.58	74.44 $\pm$ 4.95	76.84 $\pm$ 1.70	85.28 $\pm$ 1.99	76.78 $\pm$ 2.69
P13	74.00 $\pm$ 5.18	80.40 $\pm$ 5.72	80.92 $\pm$ 1.72	91.16 $\pm$ 1.92	80.66 $\pm$ 2.80
P14	77.96 $\pm$ 4.74	85.44 $\pm$ 5.99	85.64 $\pm$ 1.89	96.24 $\pm$ 1.84	84.60 $\pm$ 2.86
P15	83.80 $\pm$ 5.58	90.48 $\pm$ 6.86	90.72 $\pm$ 2.15	100.68 $\pm$ 2.19	89.48 $\pm$ 2.98
P16	88.80 $\pm$ 5.62	96.32 $\pm$ 7.07	95.80 $\pm$ 2.77	106.72 $\pm$ 2.25	95.20 $\pm$ 3.04
P17	94.64 $\pm$ 6.03	101.92 $\pm$ 7.63	103.04 $\pm$ 2.86	111.68 $\pm$ 2.01	100.36 $\pm$ 2.82
P18	99.60 $\pm$ 5.64	107.68 $\pm$ 8.53	107.92 $\pm$ 3.25	117.36 $\pm$ 2.52	105.84 $\pm$ 2.71
P19	105.81 $\pm$ 5.80	114.74 $\pm$ 9.48	114.40 $\pm$ 3.55	123.48 $\pm$ 2.23	111.36 $\pm$ 2.79
P20	110.94 $\pm$ 6.22	121.76 $\pm$ 9.67	121.36 $\pm$ 4.18	129.92 $\pm$ 2.52	116.60 $\pm$ 3.25
P21	116.84 $\pm$ 7.07	127.32 $\pm$ 9.71	128.08 $\pm$ 4.51	135.76 $\pm$ 3.24	122.48 $\pm$ 3.64
P22	122.72 $\pm$ 7.01	134.24 $\pm$ 10.22	134.12 $\pm$ 4.39	142.24 $\pm$ 2.93	128.20 $\pm$ 4.28
P23	129.62 $\pm$ 7.56	140.24 $\pm$ 10.41	141.84 $\pm$ 4.30	148.16 $\pm$ 2.69	134.68 $\pm$ 4.37
P24	136.16 $\pm$ 7.98	146.24 $\pm$ 10.62	150.16 $\pm$ 4.82	154.52 $\pm$ 2.98	140.64 $\pm$ 4.49
P25	142.96 $\pm$ 8.46	152.96 $\pm$ 11.05	157.08 $\pm$ 4.74	161.56 $\pm$ 2.95	145.80 $\pm$ 4.68
P26	150.40 $\pm$ 9.29	160.68 $\pm$ 11.82	164.44 $\pm$ 4.84	168.04 $\pm$ 3.25	150.44 $\pm$ 5.03
<b>Post-weaning Mean</b>	<b>101.46<sup>a</sup> <math>\pm</math> 3.33</b>	<b>110.10<sup>bc</sup> <math>\pm</math> 3.69</b>	<b>111.38<sup>c</sup> <math>\pm</math> 3.34</b>	<b>119.27<sup>d</sup> <math>\pm</math> 3.15</b>	<b>107.30<sup>b</sup> <math>\pm</math> 2.92</b>
<b>Overall Mean</b>	<b>78.71<sup>a</sup> <math>\pm</math> 3.34</b>	<b>85.79<sup>b</sup> <math>\pm</math> 3.63</b>	<b>86.46<sup>b</sup> <math>\pm</math> 3.57</b>	<b>93.09<sup>c</sup> <math>\pm</math> 3.62</b>	<b>84.24<sup>b</sup> <math>\pm</math> 3.25</b>

Means with different superscript in row (a-c) differ significantly ( $p < 0.01$ ), showing treatment effect.

was significantly ( $p < 0.05$ ) higher than all other groups. It was in close agreement with Borderas *et al.* (2009), who reported that in the initial weeks of life, solid feed intake of calves were higher in low milk group due to inadaptability of calves under low milk feeding levels, whereas  $T_5$  showed the lowest intake (111.95 g/day). The declining trend of TMR-1 intake with increasing milk level suggests a substitution effect, wherein higher milk consumption suppressed early starter intake. This reflects delayed rumen stimulation in high-milk-fed calves during the initial phase. In contrast, TMR-2 (65:35) intake was significantly ( $p < 0.05$ ) higher in  $T_3$  (4417.40 g/day), followed by  $T_4$ , while  $T_1$  recorded the lowest value. The greater TMR-2 intake in moderate milk groups ( $T_3$  and  $T_4$ ) indicates improved rumen development and a smoother transition from liquid to solid feeding. The comparable intake in  $T_2$  and  $T_5$  suggests that both insufficient and excessive milk allowance may limit optimal post-weaning solid feed adaptation.

Overall, the data demonstrate that higher milk feeding reduced early starter (TMR-1) intake but did not proportionally enhance later solid feed (TMR-2) consumption. Moderate milk allowance ( $T_3$ - $T_4$ ) appeared to achieve a better balance between liquid and solid feed intake, thereby potentially supporting improved rumen development, post-weaning adaptation and attain maximum weight gain. The present findings are consistent with Khan *et al.* (2007), who reported that higher milk allowance improved post-weaning DM intake, possibly due to enhanced rumen capacity development.

### Growth Response and Feed Cost

The total body weight gain of experimental calves during pre-weaning, post-weaning, and overall experimental periods including feed cost parameters is presented in Table 4. During the pre-weaning phase, body weight gain differed significantly ( $p < 0.05$ ) among treatments. Calves under treatment  $T_4$  recorded the highest pre-weaning weight gain, which was significantly higher than  $T_1$  (Control), while remaining comparable with  $T_3$  and  $T_5$ . The lowest pre-weaning gain was observed in  $T_1$ , reflecting the influence of restricted milk allowance during early growth. In contrast, post-weaning body weight gain did not differ significantly ( $p > 0.05$ ) among treatments. Although numerically higher gains were observed in  $T_3$  and  $T_2$ , the calves under  $T_5$  recorded comparatively lower gains. The absence of significant differences during the post-weaning period suggests the occurrence of compensatory growth. Consequently, overall body weight gain among treatments did not differ significantly, despite numerical superiority in  $T_3$  and  $T_4$ . In which, the calves under  $T_4$  group attained the highest body weight gain (135.52 kg) during the entire experiment as compared to other milk feeding treatments.

The rearing feed cost of experimental calves was calculated based on prevailing market prices and actual feed consumption. The average feed cost incurred on milk,

TMR-1, and TMR-2 constituted 40.58, 8.60, and 50.82% of the total feed cost, respectively, indicating that liquid feeding remained a major contributor to rearing expenses. The total feed cost per calf was significantly ( $p < 0.01$ ) influenced by different milk feeding protocols, with the highest cost recorded in  $T_4$  and the lowest in  $T_1$ . However, pre-weaning and post-weaning feed costs individually were not significantly affected, suggesting that cumulative milk intake primarily influenced overall expenditure.

The average feed cost per kg body weight gain was higher during the pre-weaning phase compared to the post-weaning phase across all treatments. Although numerical variations were observed among different milk feeding protocols, the overall feed cost per kg gain did not differ significantly among treatments. Although calves fed higher milk allowances recorded numerically higher feed cost per kg body weight gain, the differences among treatments were statistically non-significant, indicating that enhanced milk feeding supported better growth performance without imposing a significant additional cost burden. Notably, calves under restricted milk feeding ( $T_1$ ) exhibited lower daily and total feed costs, whereas higher milk feeding protocols resulted in superior pre-weaning growth. These findings suggest that increased milk allowance improves early growth performance, while restricted milk feeding remains economically efficient by achieving comparable overall growth through post-weaning compensatory gain. The average daily feed cost in experimental calves was significantly ( $p < 0.01$ ) influenced by different milk feeding protocols during the experiment. The  $T_1$  group of calves had significantly ( $p < 0.01$ ) lower values than the other protocols. These findings demonstrate that higher milk feeding strategies improved early growth but substantially increased numerical rearing costs compared to the restricted group. Arens *et al.* (2023) supported the present finding. Whereas, Gamit *et al.* (2024) reported that rearing crossbred calves under high milk feeding significantly increased the feed cost per kg body weight gain and daily feed cost.

The present results are consistent with earlier reports suggesting that higher milk allowance enhances pre-weaning growth but does not necessarily improve overall growth due to post-weaning compensatory gain (Drackley, 2008; Uys *et al.*, 2011). Similarly, previous studies have reported higher rearing costs in calves fed higher milk allowances compared to restricted milk feeding regimes (Dhangar, 1989; Patel, 2022). Thus, restricted milk feeding protocols appear to offer a more economical rearing strategy while achieving comparable overall growth performance.

### Water Intake (L/day)

The water intake of crossbred calves differed significantly ( $p < 0.01$ ) among milk feeding protocols during pre-weaning, post-weaning, and overall experimental periods (Table 4). During the milk-feeding phase,  $T_1$  calves exhibited significantly higher water intake ( $1.20 \pm 0.19$  L/d) compared



**Table 4:** Feed & water intake, body weight gain, and feed cost of rearing of experimental calves under different milk feeding regimes (Mean  $\pm$  SE)

Particulars	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	Overall
<b>Feed Intake (DM basis, g/day)</b>						
Milk	504.00 $\pm$ 0.00	658.00 $\pm$ 16.21	707.00 $\pm$ 19.40	756.00 $\pm$ 22.83	805.00 $\pm$ 26.40	686.00 $\pm$ 10.98
TMR-1 (75:25)	320.20 <sup>c</sup> $\pm$ 55.99	220.36 <sup>b</sup> $\pm$ 39.39	198.80 <sup>b</sup> $\pm$ 33.88	205.02 <sup>b</sup> $\pm$ 32.11	111.95 <sup>a</sup> $\pm$ 20.03	211.27 $\pm$ 17.47
TMR-2 (65:35)	3873.52 <sup>a</sup> $\pm$ 191.43	4041.58 <sup>ab</sup> $\pm$ 193.27	4417.40 <sup>c</sup> $\pm$ 223.41	4340.57 <sup>bc</sup> $\pm$ 200.70	4029.52 <sup>ab</sup> $\pm$ 204.19	4140.52 $\pm$ 90.87
<b>Water Intake (L/Day)</b>						
Pre-weaning	1.20 <sup>b</sup> $\pm$ 0.19	0.93 <sup>a</sup> $\pm$ 0.14	0.92 <sup>a</sup> $\pm$ 0.13	0.93 <sup>a</sup> $\pm$ 0.12	0.78 <sup>a</sup> $\pm$ 0.10	0.95 $\pm$ 0.06
Post-weaning	15.07 <sup>a</sup> $\pm$ 0.81	15.82 <sup>a</sup> $\pm$ 0.80	17.73 <sup>c</sup> $\pm$ 0.97	17.38 <sup>bc</sup> $\pm$ 0.84	16.25 <sup>ab</sup> $\pm$ 0.89	16.45 $\pm$ 0.39
Overall Mean	10.27 <sup>a</sup> $\pm$ 0.79	10.66 <sup>a</sup> $\pm$ 0.81	11.91 <sup>b</sup> $\pm$ 0.95	11.68 <sup>b</sup> $\pm$ 0.88	10.89 <sup>a</sup> $\pm$ 0.87	11.08 $\pm$ 0.39
<b>Total Expenditure of Feed (Rs.)</b>						
Milk	9072.00 $\pm$ 0.00	11844.00 $\pm$ 0.00	12726.00 $\pm$ 0.00	13608.00 $\pm$ 0.00	14490.00 $\pm$ 0.00	12348.00 $\pm$ 0.00
TMR-1 (75:25)	2988.56 $\pm$ 415.64	2571.40 $\pm$ 212.76	2627.11 $\pm$ 197.36	2734.35 $\pm$ 221.28	2153.99 $\pm$ 161.80	2615.08 $\pm$ 118.91
TMR-2 (65:35)	14257.15 $\pm$ 1432.46	15200.20 $\pm$ 930.27	16534.03 $\pm$ 797.97	16169.69 $\pm$ 960.99	15170.49 $\pm$ 962.97	15466.31 $\pm$ 455.29
Total Cost	26317.71 <sup>a</sup> $\pm$ 1736.91	29615.60 <sup>ab</sup> $\pm$ 1124.84	31887.15 <sup>b</sup> $\pm$ 990.84	32512.05 <sup>b</sup> $\pm$ 948.99	31814.48 <sup>b</sup> $\pm$ 911.90	30429.40 $\pm$ 670.40
<b>Total B.Wt Gain (Kg)</b>						
Pre-weaning	27.06 <sup>a</sup> $\pm$ 1.68	30.00 <sup>ab</sup> $\pm$ 4.46	36.64 <sup>bc</sup> $\pm$ 1.39	38.84 <sup>c</sup> $\pm$ 0.72	35.52 <sup>bc</sup> $\pm$ 1.87	33.61 $\pm$ 1.32
Post-weaning	94.70 $\pm$ 6.62	97.92 $\pm$ 8.09	98.76 $\pm$ 3.81	96.68 $\pm$ 2.57	84.32 $\pm$ 4.22	94.47 $\pm$ 2.46
Overall	121.76 $\pm$ 7.79	127.92 $\pm$ 12.02	135.40 $\pm$ 4.89	135.52 $\pm$ 2.79	119.84 $\pm$ 4.85	128.08 $\pm$ 3.23
<b>Feed Cost (Rs.) per kg Gain</b>						
Pre-weaning	452.02 $\pm$ 28.07	561.97 $\pm$ 1.37	421.14 $\pm$ 15.15	421.33 $\pm$ 9.69	474.51 $\pm$ 28.38	466.20 $\pm$ 28.47
Post-weaning	149.73 $\pm$ 10.32	156.74 $\pm$ 6.42	168.83 $\pm$ 11.97	167.60 $\pm$ 10.60	181.97 $\pm$ 15.94	164.98 $\pm$ 5.19
Overall	216.17 $\pm$ 5.09	238.07 $\pm$ 18.53	236.94 $\pm$ 12.43	240.09 $\pm$ 7.07	266.97 $\pm$ 12.01	239.65 $\pm$ 5.90
<b>Overall Feed Cost (Rs.) per Day</b>						
Per Day Cost	144.60 <sup>a</sup> $\pm$ 4.32	162.72 <sup>b</sup> $\pm$ 5.18	175.20 <sup>b</sup> $\pm$ 5.81	178.63 <sup>b</sup> $\pm$ 5.84	174.80 <sup>b</sup> $\pm$ 6.48	167.19 $\pm$ 2.53

Means with different superscript in row (a-c) differ significantly ( $p < 0.01$ ), showing treatment effect.

to T<sub>2</sub>-T<sub>5</sub> groups, which remained statistically comparable. The more water intake in T<sub>1</sub> calves might be due to restricted milk supply and high dry matter intake during milk feeding phase. The calves under T<sub>2</sub> to T<sub>5</sub> groups consume less water (22.5 to 35.0%) as compared to restricted milk feeding group T<sub>1</sub>. In which, calves of T<sub>5</sub> group consume comparatively very low amount of water than other groups, due to greater milk allowance and reduced dry matter intake, supporting the inverse relationship between milk consumption and voluntary water intake (De-Passille *et al.*, 2011; Broucek, 2019).

Post-weaning, water intake increased markedly across all treatments ( $p < 0.01$ ), with T<sub>3</sub> and T<sub>4</sub> calves recording the highest intake (17.73  $\pm$  0.97 and 17.38  $\pm$  0.84 L/d, respectively), coinciding with greater dry matter intake and improved growth performance. The marked rise in water consumption following weaning reflects the transition to sole TMR feeding and enhanced rumen activity. Voluntary water intake emerged as a functional driver of post-weaning growth efficiency, showing a positive association with starter intake

and body weight gain. Enhanced rumen hydration likely facilitated microbial colonization and fermentation efficiency, thereby improving nutrient utilization and reducing feed cost per kg gain. Thus, water intake may serve as a practical physiological indicator of feed efficiency and economic sustainability in intensified milk-feeding systems.

Across the entire experimental period, calves under T<sub>3</sub> and T<sub>4</sub> protocols demonstrated significantly greater ( $p < 0.01$ ) overall water intake compared to other treatments. The observed trends corroborated earlier findings that restricted milk feeding promotes higher drinking water intake and that water consumption is positively associated with starter intake and rumen development (Kertz *et al.*, 1984; Hepola *et al.*, 2008; Patel, 2022).

## CONCLUSION

The newborn crossbred calves reared on high milk feeding protocols (T<sub>3</sub>, T<sub>4</sub>) attained significantly ( $p < 0.01$ ) higher body weight gain as compared to calves reared on the restricted

milk feeding protocol ( $T_1$ , 4 lit/day). The feed cost per kg gain was at par between the high milk feeding group ( $T_2$  to  $T_5$ ) and the restricted milk feeding group ( $T_1$ ). Overall, moderate high milk feeding protocols ( $T_3$  and  $T_4$ ) optimized post-weaning water intake, which was positively associated with rumen development, growth performance, and feed efficiency in early-weaned crossbred calves. Thus, the early-weaned crossbred calves can be reared on  $T_3$  and  $T_4$  milk feeding protocols (1.0 & 1.5 lit higher than  $T_1$  from day 15 with a weekly increment of 0.5 lit till 7<sup>th</sup> week and then step-down @ same rate till 9<sup>th</sup> week of age) to maximize their body weight gain.

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