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Research Article

EFFECT OF HIGH ENERGY AND PROTEIN ON INTAKE, GROWTH, DIGESTIBILITY, FEED EFFICIENCY AND COST OF FEEDING IN CROSSBRED HEIFERS

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Abstract: The experiment was planned to assess the effect of feeding higher energy-protein and higher protein total mixed ration on growth, intake, and digestibility of nutrients as well as feed utilization efficiency in crossbred heifers. Twenty-one healthy crossbred heifers (75% Holstein Friesian x 25%Kankrej) of similar age and body weight were selected and grouped into three (T1, T2, T3) having seven in each group. The crossbred heifers were fed total mixed ration-TMR to meet the requirements of 100 % each of ME and CP of ICAR (2013) (T1; control), T2- 125% each of ME and CP of control and T3 100% ME and 125% CP of control for 140 days. Intake of dry matter, crude protein and metabolic energy were found significantly higher (p<0.01) in heifers fed a high T2 TMR compared to the T1 and T3 TMR when expressed daily, per cent basis and on a metabolic BW basis. The daily gain in body weight of crossbred heifers was higher (P<0.05) in the T2 group than T3 and T1 group. The digestibility of CP and CF of TMR was significantly increased (p<0.05) in the T3 group compared to T1 and T2 group. The reduced digestibility of OM, NFE, NDF and ADF of T2 TMR (six per cent fat; p<0.05) was observed compared to T1 TMR. The nutritive value of high energy-crude protein TMR was slightly lower than the control TMR owing to lower digestibility of OM, NFE, NDF and ADF. The feed cost per kg gain was lower in the T2 (-31.31 ₹) and T3 (-39.25 ₹) group compared to the control group (T1). The feeding of high-energy crude protein TMR economically feasible option to improve the growth rate of crossbred heifers.

Keywords: *Crossbred heifer, Digestibility, Energy, Feed cost, Feed efficiency, Growth, Intake*

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Introduction

Livestock contributes about 13% of global calories and 28% of protein by providing meat, milk, eggs, manure, and through transport [1]. They also contribute significantly to meeting several socioeconomic needs globally and locally. The demand for livestock products is globally increasing owing to human population growth, improved income and urbanization. Protein and energy are the two constituents of diets, having a vital role in the growth, production, and reproduction of dairy animals that minimizes resource input and nutrient output [2]. A well-balanced energy and protein ration are important for nutrient utilization, growth, reproduction and production potentials [3]. The higher energy protein in the diet is important for growth and nutrient utilization [4,5]. The feed utilization efficiency was improved by feeding a higher protein diet to heifers [3]. Based on these observations the experiment was planned to assess the effect of feeding higher energy-protein and higher protein total mixed ration on growth, intake and digestibility of nutrients as well as feed utilization efficiency in crossbred heifers.

Materials and Methods

Location and grouping

The present research study was conducted at Livestock Research Station, Anand Agricultural University, Anand for the period of 140 days (ten bi-weekly periods) from 16/07/2022 to 04/12/2022 with approval of Committee for the Purpose of Control and Supervision of Experiments on Animals-CPCSEA (No. 364/LRS/2022), New Delhi on the recommendation of Institutional Animal Ethics Committee (IAEC). Experimental heifers were cared for and managed as per directives. Twenty-one healthy crossbred heifers (75% Holstein Friesian x 25%Kankrej) of similar age (T1-383.62±26.68, T2-376.13 ±27.12, T3-373.12 ±27.22 days) and body weight (T1-269.72±10.45, T2- 271.2 ±9.31, T3-272.08±7.90 kg) were selected and grouped into the three (T1, T2, T3) having seven in each group, considering the body weight and age.

TMR preparation and Feeding

The crossbred heifers were fed TMR [Table-1]: T1 (control)- 100 % each of ME and CP of ICAR (2013) [6], T2- 125% each of ME and CP of control (TMR T2 was prepared 110% each of ME and CP of control and was fed 1.136 higher of control) and T3- 100% ME and 125% CP of control (TMR was prepared 100% ME and 125% CP of control). All TMRs were prepared for the expected final highest body weight (370 kg) of crossbred heifers and the CP requirement for the lower body weight was met with supplementation of Distillery Dried Grain with Soluble (DDGS). The ME of ingredients was considered from the NRC (2001) [7,8], and of ingredients whose, ME was not available as well as of TMR was calculated [7] using the formula ME (Mcal/kg) = TDN (%) × 0.0361. The feed offered to crossbred heifers was adjusted at weekly intervals based on changes in body weight. TMRs were made on a clean cemented floor on daily basis and fed two times a day (10:00, 14:00 hr). The crossbred heifers were let loose for two hours in the morning under controlled conditions for exercise. The clean, wholesome and fresh drinking water was freely available during exercise and also offered two times (14:00, 17:00 hrs) in a day at a tying place.

Body weight, Intake and Digestibility

The crossbred heifers were weighed weekly before feeding and watering in the morning (8:00- 8:45 hrs) on the electronic weighing bridge. The data on body weight was analyzed at biweekly intervals. Intake of dry matter and nutrients were calculated at a biweekly interval based on feed offered and the next day left over.

Table-1 Ingredient and nutrients composition of total mixed ration (TMR) fed to crossbred heifers

Particular	TMR-T1	TMR-T2	TMR-T3
Ingredient proportion (kg) on DM basis			
CCM	14.01	19.88	23.29
Maize Bhardo	15.00	15.00	13.82
Soybean DOC	0.00	0.00	0.84
Wheat straw	20.00	19.00	17.73
Pigeon pea straw	20.00	13.11	18.15
Green Hybrid Napier	25.00	25.00	23.31
Premix*	1.00	1.00	1.00
Salt	1.00	1.00	1.00
Bypass fat	3.99	6.00	0.86
Total	100.00	100.00	100.00
Chemical composition % on DM basis			
DM	51.27 ±0.72	51.45 ±0.89	52.98 ±0.51
OM	86.19 ±1.31	87.34 ±0.63	86.59 ±1.06
CP	8.85 ±0.15	10.03 ±0.17	11.43 ±0.24
EE	6.57 ±0.64	7.87±0.93	3.76±0.24
CF	33.20 ±1.33	31.80 ±0.94	31.67 ±0.95
Total Ash	8.53 ±0.31	8.37±0.13	8.70±0.22
NFE	42.84 ±0.73	41.94 ±0.59	44.43 ±0.79
NDF	68.38±1.74	65.28±2.44	64.37±1.40
ADF	38.35±0.56	35.59±0.99	34.90±0.64
Cal. ME (Mcal/kg)	2.212	2.391	2.159

** Premix Each kg contained 202g Calcium, 11.8g Phosphorus, 10g Magnesium, 5.4g Sodium, 9g Sulphur, 12.76g Zinc, 1g Copper, 0.125g Cobalt, 4g Manganese, 0.03g Selenium, 0.4g Iodine, 6g Iron, 0.02g Chromium, 1100000 IU Vitamin A, 220000 IU Vitamin D3, 200mg Vitamin E, 8.8 mg Vitamin B12, 2759 mg Niacin, 5000mg Methionine activity and 10000mg Lysin.*

Table-2 Dry matter, nutrients and energy intake of crossbred heifers fed different TMR

Parameter	T1	T2	T3	P value
DM (kg/day)	7.23^{c}±0.21	8.73^{a} ±0.15	7.63^{b} ±0.13	0.000
DM (kg/100 kg BW)	2.27^{b}±0.04	2.67^{a} ±0.05	2.30^{b} ±0.03	0.000
DM (g/kg $W^{0.75}$)	95.75^{c}±1.04	113.32^{a}±1.61	99.20^{b} ±0.58	0.000
CP (kg/day)	0.66^{b} ±0.01	0.91^{a} ±0.01	0.89^{a} ±0.01	0.000
CP (kg/100 kg BW)	0.21^{b} ±0.01	0.28^{a} ±0.01	0.27^{a} ±0.00	0.000
CP (g/kg $W^{0.75}$)	8.80^{b} ±0.16	11.76^{a} ±0.15	11.62^{a} ±0.08	0.000
Cal. ME (Mcal/day)	16.02^{b} ±0.43	20.88^{a} ±0.33	16.50^{b} ±0.25	0.000
Cal. ME (Mcal/ 100 kg BW)	5.03^{b} ±0.09	6.38^{a} ±0.12	5.05^{b} ±0.042	0.000
Cal. ME (kcal/kg $W^{0.75}$)	212.12^{b} ±2.33	271.12^{a} ±3.85	214.50^{b} ±1.26	0.000

Table-3 Body weight of crossbred heifers fed different TMR

Parameter	T1	T2	T3	P value
Initial BW	267.4±11.79	267.43±9.95	267.97±8.39	-
Final BW	350.31±13.16	369±10.13	365.2±7.47	-
Average BW (kg)	318.28±11.58	327.14+9.82	325.54±6.50	0.304
BW gain (kg/day)	0.592^{b}±0.04	0.730^{a}±0.03	0.694^{b}±0.03	0.008

The digestibility of dry matter and nutrients of TMR in all groups were measured for seven days after 90 days of experimental feeding. The measured quantity of feed offered and records of leftovers, as well as faeces voided, was kept during the digestion trial. The samples of TMR offered, leftover and faeces were analyzed for proximate principles as per AOAC (1995) [9] and fibre fractions as per Van Soest *et al*. (1991) [10].

Feed conversion and feed cost

The nutrient intake to gain each kg gain in body weight was calculated based on the intake and body weight gain of crossbred heifers. The total cost of the feed, cost per heifer per day, and cost per kg body weight gain were calculated based on daily intake and the cost of TMR. The cost of TMR was worked out based on the purchasing price of ingredients except Hybrid Napier grown on a University farm, the cost of which was taken as the University selling price.

Statistics

The data were presented as the mean of treatment with standard error. The data were analyzed as per Snedecor and Cochran (2014) [11] as one-way ANOVA using Web-based Agriculture Statistic software Package- WASP 2.0 developed by Jangam, A. K. and Wadekar, P. N. of Central Coastal Agricultural Research Institute, Indian Council of Agricultural Research, Goa, India. The difference between the mean was taken as significant at probability <0.05. https://ccari.icar.gov.in/wasp2.0/index.php

Results and Discussion

Feed and nutrient intake in crossbred heifers

The nutrient composition of TMRs is given in [Table-1]. The effect of high ME+CP and high CP diet on intake and dry matter and nutrients in crossbred heifers are presented in [Table-2]. Intake of dry matter, crude protein, and metabolic energy were found significantly higher (p<0.01) in heifers fed a high ME+CP TMR compared to the T1 and T3 TMR when expressed daily, percent basis, and on a metabolic BW basis. Only crude protein intake of heifers was improved significantly (p<0.01) in the high protein group (T3) compared to the control group (T1).

The intake of DM, CP, and ME was higher on feeding a high-energy protein diet and only CP intake was improved in a high protein diet in crossbred heifers. The regulation of dry matter intake is a complex mechanism based on the stimulation as well as inhibition signals owing to energy balance between consumption and requirement, physical fill/distension of rumen reticulum, feed sensory effect, feed habit factors, NDF content, NDF degradability, fermentable carbohydrate content, diet content of unsaturated, saturated, and chain length of fatty acids, liver metabolism, ruminal fluid osmolarity, fuel sensing by tissue and roughage to concentrate ratio [12,13]. In the present experiment, a 110% higher density of energy and protein in the TMR (T2) fed 1.136 times higher than control has improved intake in crossbred heifers. Similarly, feeding high energy diet [4]; high energy and protein diet [5], and a high protein diet [14, 15] to heifers resulted in improved DM, CP and ME intake.

Table-4 Plane of crude protein and energy nutrition of crossbred heifers fed different TMR

Parameter	T1			T2			T3		
	Intake	Req.	% of req.	Intake	Req.	% of req.	Intake	Req.	% of req.
CP (kg/d)	0.662 ±0.01	0.640 ±0.02	104.45	0.905 ±0.01	0.708 ±0.02	128.10	0.893 ±0.01	0.691 ±0.01	129.33
ME (Mcal/d)	16.015 ±0.46	14.766 ±0.60	108.95	20.977 ±0.36	16.580 ±0.63	126.76	16.500 ±0.27	15.921 ± 0.37	103.85

Table-5 Nutrient digestibility and digestible nutrients intake of crossbred heifers fed different TMR

Parameter	T1	T2	T3	P Value
Digestibility %				
DM	57.65±0.77	56.16±0.80	58.94±0.80	0.073
OM	59.65^{a} ±1.23	56.60^{b}±0.54	61.57^{a}±0.99	0.006
CP	65.47^{b} ±1.33	63.59^{b} ±0.90	70.54^{a} ±1.06	0.001
EE	83.61±2.36	79.49±1.44	81.56±1.63	0.315
NFE	64.19^{a} ±1.75	57.13^{b} ±1.15	63.50^{a} ±1.60	0.007
CF	43.09^{b} ±1.27	39.76^{b} ±0.97	50.03^{a} ±1.24	0.000
NDF	52.31^{a} ±1.11	43.30^{b}±1.55	49.29^{a} ±1.29	0.001
ADF	40.73^{a} ±1.55	30.18^{c}±0.94	35.50^{b}±1.78	0.000
Nutritive value				
DCP %	5.79	6.38	8.06	
TDN %	59.96	57.07	59.03	
Actual ME (Mcal/kg)	2.164	2.060	2.130	
Intake				
DCP (kg/day)	0.38^{c}±0.01	0.57^{b}±0.01	0.73^{a}±0.01	0.000
DCP (kg/100 kg BW)	0.12^{c}±0.00	0.17^{b}±0.00	0.22^{a}±0.002	0.000
DCP (g/kg $W^{0.75}$)	5.04^{c}±0.08	7.41^{b}±0.09	9.50^{a}±0.07	0.000
AME (Mcal/d)	15.639^{b}± 0.42	17.965^{a}± 0.29	16.269^{ab}± 0.27	0.000
AME (Mcal/ 100 kg BW)	4.909^{b}±0.09	5.493^{a}±0.11	4.979^{b}±0.04	0.000
AMEI (Kcal/ kg $W^{0.75}$)	207.117^{b}± 2.24	233.313^{a}±3.32	211.502^{b}±1.24	0.000

Table-6 Feed conversion ratio and feed cost in different crossbred heifer groups

Parameter	T1	T2	T3	P value
Feed conversion ratio				
kg DM/ kg gain	12.55±0.93	12.16±0.54	11.10±0.51	0.327
kg CP/ kg gain	1.15±0.08	1.26±0.05	1.30±0.06	0.292
kg DCP/ kg gain	0.66^{c} ±0.05	0.79^{b} ±0.03	1.06^{a} ±0.05	0.000
Calculated ME Mcal / kg gain	27.80±2.06	29.09±1.28	24.01±1.10	0.078
Actual ME Mcal/ kg gain	27.15±2.01	25.03±1.10	23.67±1.09	0.266
Cost of feed				
Total feed cost ₹/ heifer	25305.44^{b} ±681.09	28370.60^{a} ±467.67	26396.38^{b} ±411.50	0.003
Av. Feed cost ₹/day/heifer	179.47^{b} ±4.83	201.21^{a} ±3.32	187.21^{b}±2.92	0.003
Feed cost ₹/kg Gain	311.62 ±23.05	280.31±12.14	272.37±12.42	0.239
Change over control		-31.31	-39.25	
Percent change over control		-10.05	-12.60	

The higher level of CP in the diet only improved the CP intake of heifers [16, 3]. In contrast to the present findings, Li *et al*. (2014) [17] reported a lower ($p<0.01$) DMI in growing cattle fed a high energy ration than a low energy ration (6.76 HE vs. 7.48 LE, kg/d) during the finishing phase.

Body weight of crossbred heifers

The daily gain in body weight of crossbred heifers [Table-3] was higher ($P<0.05$) in the T2 group than in other (T3, T1) groups. The average body weight of heifers in different TMR groups differed only non-significantly ($p>0.05$).

The higher energy protein intake by crossbred heifers was utilized for higher daily body weight gain. The feeding of energy protein densified diet to heifers translated to body weight gain [4, 5] while mean body weight was without significant effect [3, 17, 14] supported the present findings. The daily gain in body weight is the function of genetic potentiality and optimum nutrition to realize the genetic potential of dairy heifers [18]. Williams *et al*. (2022) [4] indicated a significant effect of densified diet on the average body weight of heifers.

Plane of nutrition

The crude protein intake of crossbred heifers in the T1, T2, and T3 groups was 104.45, 128.10, and 129.33 percent of the requirement which was near to treatment protocol. The metabolizable energy intake of crossbred heifers in T1, T2, and T3 groups was 108.95, 126.76, and 103.85 percent of the requirement [Table-4] which was near to treatment protocol. The deviation in terms of percent protein requirement of crossbred heifers fed T1, T2 and T3 TMR were 4.45, 3.10, and 4.33 percent higher than the treatment protocol and that of the energy was 8.95, 1.76, and 3.85 percent higher.

Digestibility and Digestible Nutrient Intake

The data on nutrient digestibility and digestible nutrient intake are given in [Table-5]. The digestibility (%) of dry matter (56.16-58.94) and ether extract (79.49-83.61) of TMR did not differ significantly ($p>0.05$). The digestibility of CP and CF of TMR was significantly increased ($p<0.05$) in the high CP TMR group compared to the T1 and T2 groups. The nutritive value of high energy-crude protein TMR was slightly lower than the control TMR owing to lower digestibility of OM, NFE, NDF, and ADF.

The reduced digestibility (%) of OM, NFE, NDF, and ADF of high ME+CP TMR (six percent fat; $p<0.05$) compared to T1 TMR in the present experiment. The high intake of fat-energy in a high-energy protein diet (16.02 vs. 20.88 Mcal/day) might have interfered with the fibre degradation in the rumen and depressed the total tract digestibility of TMR fed to crossbred heifers in the present study. Frank *et al*. (2022) [19] reasoned that some soluble parts of inert fat interfere with the rumen degradation and total tract digestibility was in line with the present findings and also reported the lower digestibility of DM, CF, NDF, and ADF of high-fat TMR in lactating HF cows. Zanton and Heinrichs (2016) [20] reported lower starch and NDF digestibility in heifers fed a high-energy diet. However, Gabler and Heinrichs (2003b) [15] and Dong *et al*. (2016) [3] stated a non-significant effect on dry matter digestibility on feeding densified feed in Holstein heifers and Chinese Holstein heifers, respectively. Whereas Williams *et al*. (2022) [4] showed higher DM and OM digestibility in Holstein dairy heifers fed energy densified diet.

The feeding of high CP TMR improved the digestibility of CP and CF of TMR compared to control (T1) TMR. The digestibility of ADF of TMR was significantly reduced in high ME-CP (T3) TMR followed by high CP (T2) and then control (T1) TMR.

The feeding of high protein diets flourished nitrogen-sensitive rumen microorganisms like total bacteria, anaerobic fungi, methanogens, protozoa, and cellulolytic bacteria, as well as microbial diversity in dairy cows, resulted in higher digestibility [21]. A trend of linear increased crude protein digestibility on feeding an increasing CP diet was observed in lactating dairy cows [22, 23, 3, 24]. Though nitrogen-sensitive microbes flourish in protein-rich diets, electron transport phosphorylation and substrate-level phosphorylation coupled to glucose fermentation in the ruminal microbiome have no effect on rumen energy and microbial protein yield [25] leading to no effect or reducing the impact on digestibility of carbohydrate fractions. In our research, the digestibility of DM, OM, EE, NFE, and NDF was not impacted by the high level of protein whereas ADF digestibility was reduced compared to control TMR. The reported parameters on digestibility of DM, OM, NDF, and ADF [22]; of DM, NDF, and ADF [23], and that of DM [3] were not impacted by higher CP diets. In contrast to our findings, [24, 15] reported higher digestibility of DM, OM, NDF, and ADF by feeding higher CP diets in dairy cows and dairy heifers, respectively.

The DCP intake (kg/day, kg/100kg BW, g/kg W0.75) was significantly higher ($p<0.01$) in the high CP diet followed by high ME+CP and then the control diet. The actual ME intake (Mcal/100kg BW, Kcal/kg W0.75) was reported significantly higher ($p<0.05$) in the high ME+CP group while a non-significant difference between the high CP and control group. The daily actual ME intake (Mcal/day) was significantly ($p<0.01$) higher in the T2 group compared to the T1 group whereas the T3 group was in between to T2 and T1 group. Similarly, significantly higher DCP intake on a percent body weight basis was noticed in Murrah buffalo calves by Prusty *et al*. (2016) [26] on the feeding of energy and protein densified diet compared to low energy protein diet. Akhter *et al*. (2017) [27] also observed significantly higher ($p<0.01$) DCP intake on metabolic BW in crossbred bull calves fed protein and energy-dense diet.

Feed conversion and cost of feeding

The data on feed conversion ratio is presented in [Table-6]. The feed conversion ratio (kg intake/ kg gain for DM, CP, and ME intake) in different TMR groups differed non-significantly. The DCP (kg) required to gain each kg of body weight was highest in T3 (1.06±0.05) followed by T2 (0.79±0.03) and least in T1 (0.66±0.05) which differed significantly ($p<0.01$) amongst each other.

Similarly, Lunagariya *et al*. (2019) [5], and Tauqir *et al*. (2011) [28] reported a non-significant effect of the energy-protein densified diet on feed efficiency for growth. In contrast, significant improvement in feed efficiency (DM, CP, and ME) for weight gain was noticed in Holstein heifers [4], in growing male Simmental cattle [29], in growing Angus × Chinese Xiangxi yellow cattle [17] fed a high-energy diet and in heifers [3, 14] fed higher protein diets.

Feed economic efficiency

The data on feed economic efficiency is depicted in [Table-6]. The total and daily feed cost per heifer (₹) in the T2 group of heifers was significantly higher than T1 and T3 groups. The feed cost per kg gain was lower in the high ME-CP (-31.31 ₹) and high CP (-39.25 ₹) group compared to the control group.

In a support of the present findings, higher total feed costs of intensified feeding and of densified diet in Holstein heifers were reported by Rincker *et al*. (2011) [30] and Brown *et al*. (2005) [31], respectively. Lunagariya *et al*. (2019) [5] also reported significantly higher daily costs and improved the cost of feed for body weight gain in crossbred heifers fed energy and protein-densified diet.

Conclusion

The feeding of high energy-crude protein T2 TMR resulted in improved body weight gain, feed and nutrients intake, and reduced digestibility of organic matter and carbohydrate fractions with a 10.05% lower feed cost for body weight gain in crossbred heifers. The feeding of high-energy crude protein TMR was economically viable to improve the growth rate of crossbred heifers.

Application of research: The feeding of energy and protein densified total mixed ration to crossbred heifers improves growth rate with the lower cost of feeding.

Research Category: Animal Nutrition

Abbreviations: ₹= INR= Indian Rupee, ADF= Acid detergent fibre, AME= Actual metabolizable energy, BW= Body weight, Cal. ME= Calculated metabolizable energy, CCM= Compounded Concentrate Mixture, CF= Crude fibre, CP=Crude protein, DCP= Digestible crude protein, DM=Dry matter, DOC= Deoiled cake, EE=Ether extract, kcal= Kilo calory, Mcal= Maga calory,ME= Metabolizable energy, NDF=Neutral detergent fibre, NFE= Nitrogen free extract, OM= Organic matter, P= Probability, Req.= Requirement, TDN= Total digestible nutrients, TMR= Total mixed ration, W0.75= Metabolic body weight,

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University: Anand Agricultural University, Anand, 388001, Gujarat, India
Research project name or number: Research station study

Author Contributions: PML, KNW, JHP: designed experiment, monitored experiment, and finalized manuscript; PPV: executed experiment, laboratory analysis, written manuscript; MMS, PHP: laboratory & data analysis; MMC: Monitored health of calves

Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: Livestock Research Station, Anand Agricultural University, Anand, 388001, Gujarat, India

Breed name: Crossbred heifers

Conflict of Interest: None declared

Ethical approval: Ethical approval taken from College of Veterinary Science and Animal Husbandry, Anand Agricultural University, Anand, 388001, Gujarat, India. Ethical Committee Approval Number: 364/LRS/2022

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