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Effects of Natural Pasture Hay and Concentrate-Based Total Mixed Ration on the Performance of Jersey Calves

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Abstract

The study aimed to compare the effect of natural pasture hay and concentrate-based total mixed ration (TMR) with separate feeding on dry matter and nutrient intakes, apparent digestibility, feed efficiency, body weight gain and reproductive performances of dairy calves. A total of eighteen post-weaned Jersey calves (age was 6.20 ± 1.61 months, and weighing was 90.4 ± 5.48 kg, mean ± S.D) were randomly assigned into a completely randomized design. Treatments were separate feedings of natural pasture hay and concentrate (T1) and TMR (T2). The feeding trial was carried out for 10.23 months. The calves in T2 group consumed more ($P<0.0$) dry matter (8.71kg vs.7.86 kg), crude protein (1.62 kg vs.1.32 kg), neutral detergent fiber (4.63 kg vs.4.11kg) and acid detergent fiber (3.54 kg vs.3.12 kg) compared to the calves fed T1. The calves in T2 showed higher ($P<0.05$) organic matter, neutral detergent fiber, and acid detergent fiber digestibility compared to the calves fed T1 but similar ($P<0.05$) in dry matter and crude protein digestibility. Calves in T2 group showed superior ($P<0.05$) daily weight gain (600.55 g vs. 335.18 g) and reached their first service at an average weight and age of 263.9 kg and 13.61 months, compared to 199.30 kg and 15.63 months, respectively, for T1 groups. Heifers in T2 required fewer inseminations per conception (1.12 vs. 1.75) and generated lower ($P<0.05$) total cost of production. Thus, the study recommends the TMR over separate feeding for weaned Jersey calves to increase the productive and reproductive efficiency at breeding.

Keywords: daily gain, digestibility, feed intake, *cost of production*

Introduction

In many farms, heifers often experience inadequate daily body weight gain and delayed first calving, exceeding 24 months. However, the primary goal of heifer rearing is to achieve optimal body weight at breeding age and ensure first calving by 24 months (London *et al*. 2012). Dairy heifers and dairy cows fed a balanced ration and maize stover silage based total mixed ration typically exhibit good health and productivity, feed efficiency, daily body weight gain , and with average blood protein levels of 17% and 13%, respectively (Ferlizza *et al*. 2020; Terefe *et* *al*. 2021b). Selection during separate feeding can significantly influence heifers' feed intake (Borland and Kesler, 1997; Khan *et al*. 2010).

Separate feeding of forage and concentrates often leads to dairy cattle consuming a higher proportion of concentrates, elevating the risk of ruminal acidosis (Maekawa *et al*. 2002). However, research by Coppock *et al*. (1981), Bargo *et al*. (2002), and DeVries (2011) suggests that total mixed ration (TMR) improves rumen conditions by minimizing pH fluctuations and creating a more favourable environment for rumen microbes. Utilizing TMR for dairy cows and heifers ensures a balanced intake of feed and a nutrient by circumventing individual preferences for forage and concentrates, thereby enhancing productivity (Lailer *et al*. 2010; Khan *et al*. 2010; Dejene *et al*. 2017). Maize stover and hay-based TMRs have been found to positively impact the growth and feed intake of Boran-Friesian and Holstein-Friesian dairy calves (Terefe *et al*. 2021c; Cavallini *et al*. 2023). However, despite the confirmed benefits of feeding TMR to dairy calves and heifers, there is limited evidence regarding fiber sources and inclusion levels (Terefe *et al*. 2021a; Toledo *et al*. 2023).

Effective feed management significantly influences dairy cattle performance. However, there has been minimal research conducted on TMR feeding for dairy cattle in Ethiopia, where dairy heifers often exhibit low productivity. Incorporating water and molasses into feed preparation aimed to streamline blending procedures, especially with dry hay and concentrates. This addressed challenges in effectively mixing these components due to dry hay's low moisture content. Adding water and molasses in total mixed ration feed facilitated uniform nutrient distribution and improved palatability, encouraging higher consumption. This approach managed feed consistency, aligned with cost-effective practices, and optimized nutrient delivery, enhancing overall feed quality and livestock nutrition. Therefore, this study hypothesized that TMR would enhance feed intake and digestibility, promote body weight gain, improve feed and economical efficient as well as key reproductive parameters in post-weaned female Jersey calves.

Materials and Methods

Description of the study area

The study was conducted at the Adea Berga dairy farm. The farm is located in the central highlands of Ethiopia at 9^{o} 16’28.85” N latitude and 38^{o} 23’14.59” E longitude, 70 km west of Addis Ababa. It lies at an altitude of 2500 meters above sea level. It is characterized by a cool subtropical climate with a mean annual temperature and rainfall of 18 °C and 1225 mm, respectively.

Experimental feed preparation and management

Natural pasture hay was harvested at 50% blooming stage, following the typical agronomic practice at the farm. The dominant species in the natural pasture hay included *Andropogon virginicus, Pennisetum setacium grasses,* and *Trifolium hybridum* legumes. Following harvesting, the natural pasture hay was dried and stored in a ventilated facility.

The concentrate feeds for the preparation of total mixed ration (TMR) were sourced from food processing industries in Addis Ababa city and Mojo town, Ethiopia. These ingredients included wheat bran, cotton seed cake, Noug (*Guizotia abyssinica*) seed cake, urea, molasses, and salt. Various steps were involved in producing the TMR. Initially, the natural pasture hay was chopped into pieces of 3-5 cm. Subsequently, different proportions of wheat bran, cottonseed cake, Noug seed cake, salt, and urea were weighed (dry matter basis) and mixed together (Table 1). Different suggestions are available concerning the optimal water-to-molasses ratio for dilution. The primary focus is to ensure that the resulting solution allows for efficient mixing with hay, chopped materials, raw feeds, and other components (Senthilkumar *et al*. 2016; Dejene *et al*. 2017). Molasses and water (in a ratio of three parts water to one part molasses) were then weighed and thoroughly mixed. This mixture of molasses and water was subsequently sprayed and uniformly mixed with the concentrate and chopped natural pasture. Water and molasses improved feed blending for dry hay and concentrates, ensuring even nutrient distribution and enhancing palatability, boosting consumption. Finally, the TMR was packed into bags which are important to protect moisture lose in TMR and this enables to keep uniformity by compacting concentrate and roughage feeds and then offered to the heifers. For the preparation of 100 kg of TMR, 50% natural pasture hay and 50% concentrate mixture, including urea and salt, was used.

Table 1: - Proportions of the natural pasture hay and concentrate feeds for different experimental animals (%, dry matter basis)

	Feeds						
Animals age	NPH	WB	CSC	NSC	M	Urea	Salt
4-6 months	50	14	8	14	11	1	2
6-12 months	50	12	10	12	13	1	2
12-18 months	50	10	10	9	18	1	2

NPH=natural pasture hay, WB=Wheat bran, CSC=Cotton seed cake, NSC=Noug seed cake

Before beginning the experiment, the calves received treatment with a broad-spectrum anti-helminthic (Albendazole 2500 mg), following the manufacturer's guidelines. Dosage for medications in calves is usually determined by their body weight. This approach ensures a more precise dosage, maximizing therapeutic effectiveness while reducing the risk of side effects or inadequate dosing. Calves were housed individually in well-ventilated barns with concrete floors, one-sided walls, and corrugated iron roofs to shield them from rain. The pens were equipped with appropriate drainage systems and gutters. Water was freely available to the calves. A preliminary period of fifteen days was allocated for the calves to acclimatize to the treatment diets. Additionally, the calves were allowed to exercise outside the barn from 8:00 p.m. to 8:30 p.m.

Experimental animal selection, design and treatments

In this study, eighteen post-weaned Jersey female calves (age = 6.20 ± 1.61 months, and weight =90.4 ± 5.48 kg, mean ± S.D, respectively) were selected from the farm and completely randomized design was implemented. The calves were grouped in to two treatment groups containing nine calves in each group based on their body weight. The treatments consisted of two feeding treatments: separate feeding of natural pasture hay and concentrate (T1), and their total mixed ration (T2). The diets were offered and formulated based on the nutritional requirements of post-weaned Jersey calves (NRC, 2001).

Feeding trial

The calves' initial body weights were assessed using a fixed cattle weighing balance at the onset of the experiment and continued throughout the experimental period fortnightly just before providing the morning diet. The feeding trial spanned on 10.23 months. Natural pasture hay for the separate feeding group (T1), and total mixed ration for T2 group calves were provided at 8:00 a.m., 12:00 a.m., and 6:00 p.m., while the daily requirement of concentrate portion for T1 group was divided in to two and administered twice daily at 8:00 a.m. and 6:00 p.m. Feed offer per each dietary treatment was periodically subjected to revision with changes in live body weight. The amount of the feed consumed and refused per each calves was recorded to calculate feed and nutrient intake of the calves throughout the experiment. The average daily body weight gain was computed by dividing the difference between the final and initial live weights of the calves by the total number of feeding trial periods. The feed and protein conversion efficiency of the calves were determined using the

Feed conversion efficiency= $\frac{\text{daily body weight gain}}{\text{daily dry matter intake}}$; protein conversion efficiency=$\frac{\text{daily body weight gain}}{\text{daily crude protein intake}}$.

Apparent digestibility

In this study, a total faecal collection method was employed for each calf. Faecal samples were collected over a period of 7 consecutive days at the end of the experiment. To prevent faecal-urine cross-contamination, farm personnel were assigned to clean the pens by promptly removing fresh faeces and washing the floor with high-pressure tap water dispensed through a plastic hose. Representative faecal samples, comprising 1% of the daily faecal output by weight were collected in the morning prior to offering fresh feed to the animals. These samples were then stored in a deep freezer at -20 °C until they were ready for subsequent laboratory analysis. The apparent digestibility of feed and nutrients was determined using the formula outlined by McDonald *et al*. (2002).

$$\text{Apparent DM/nutrient digestibility (\%)} = \frac{\text{DM/nutrient intake - Faecal DM/nutrient excreted}}{\text{DM/nutrient intake}} * 100$$

Reproductive performances evaluation

The evaluation of key reproductive parameters was conducted with careful attention to detail, employing a comprehensive approach to ensure thorough assessment. Age at first service, representing the pivotal moment when reproductive maturity initiates, was carefully noted. This innovative was complemented by monitoring the weight at the onset of the first oestrus or insemination, as it provides insights into the physiological readiness for breeding.

Furthermore, the age at first conception, a crucial metric indicative of reproductive efficiency, was precisely determined. This parameter sheds light on the ability of the heifers to conceive at an optimal age, thereby influencing overall herd productivity. Additionally, the number of inseminations per conception was scrutinized, offering valuable insights into breeding success rates and efficiency of reproductive management practices. The assessment methodology encompassed a combination of visual observation techniques and rectal palpation, ensuring a comprehensive understanding of reproductive health and performance. Through visual observation, subtle cues such as behavioural changes and physical indicators were noted, providing supplementary information to the palpation findings.

Rectal palpation, a fundamental tool in reproductive assessment, allowed for direct examination of the reproductive tract, enabling the identification of physiological changes indicative of breeding status and pregnancy. Moreover, a rectal examination conducted 60 days post-insemination served as a pivotal checkpoint to confirm pregnancy status and monitor early embryonic development. Following the confirmation of pregnancy, the pregnant heifers were subjected to routine husbandry practices essential for ensuring their well-being and optimizing reproductive outcomes.

Chemical Analysis

The total mixed ration and faecal samples were dried in a forced-air oven at 60 ºC for 72 hours. The samples were ground to 1 mm sieve size. All samples of feeds offered, refusals, and faeces were analysed for DM, ash and N according to AOAC (1990). Crude protein content was calculated as Nx6.25. Neutral detergent fiber, acid detergent fiber, and acid detergent lignin was determined using the method developed by Van Soest and Robertson (1985). Additionally, *in vitro* dry matter digestibility of the feed was assessed using the two-stage procedure outlined by Tilley and Terry (1963). The metabolizable energy (ME) content of the feeds was estimated from *in vitro* organic matter digestibility (IVOMD) using the equation described by McDonald *et al*. (2002), where ME (MJ/kgDM) = 0.16× IVOMD.

Cost-benefit analysis

Cost-benefit assessments were conducted by calculating the expenses, including feed costs (concentrate and native pasture hay), labour, initial animal costs, and other incurred expenses. This was compared with revenues generated from manure and lives animal sales over the course of the entire experiment. Market prices for concentrate, native pasture hay, and all other components were obtained from prevailing market rates in Holeta, Ethiopia.

The cost-benefit analysis aimed to determine the total production cost per heifer per day. The benefit-cost ratios were calculated using the following formulas:

NM=TR-TC......................... (1)
Where, NM = Net Margin; TR= Total Return; TC = Total Cost;
TC=TVC+TFC.. (2)
Where, TVC = Total Variable Cost, TFC = Total Fixed Cost

The following variables were calculated, where;

A) Gross margin (GM) is the difference between the total revenue earned and the total variable cost incurred, GM = TR-TVC.
B). Variable cost (VC) is the cost that varies with changes in output; it is a function of output level. The variable cost includes transportation, labour cost and cost of live cattle
C) Fixed Cost is the cost that does not vary with respect to output (tools and equipment).
D) Total cost is the total expenditure for the farm including addition of both variable and fixed costs TC= TFC+TVC.
E) Total revenue (TR) is the total income realized on output produced that is, quantity sold multiplied by price per unit.
F). Net Revenue is the difference between the total revenue and the total cost.
G). Cost-benefit cost ratio (BCR) is the total revenue divided by the total cost, BCR=TR/TC. When BCR is greater than 1, the business is profitable (Sarma *et al.* 2014).

Statistical analysis

The data was subjected to analysis using a single factor ANOVA using the SAS procedure (SAS, 2002). The Tukey mean separation test at the 5% level of significance was used. The following statistical model was used for the analysis.

$Yij = \mu + Xi + Eij$,

Where,

Yij = is the response variable, μ = over all mean, Xi = the treatment effect and Eij = random error.

Results and Discussion

Chemical composition of feeds

The chemical composition of the experimental feeds is presented in Table 2. Molasses and natural pasture hay exhibited lower crude protein (CP) contents compared to Noug seed cake and wheat bran. Natural pasture hay has numerically higher neutral detergent fiber (NDF) and acid detergent fiber (ADF) contents than other feeds and it has numerically lowest *in vitro* dry matter digestibility (IVOMD) and metabolizable energy (ME). Conversely, wheat bran demonstrated higher IVOMD and ME compared to other feeds. The crude protein (CP) level of natural pasture hay ranged from 4.5% to 6%, consistent with reports by Getu *et al*. (2012), Dawit *et al*. (2013), Dereje *et al*. (2017), and Terefe *et al*. (2021a). However, an earlier report by Tesfaye (2017) indicated a higher CP value (8%) in natural pasture hay, possibly influenced by agronomic practices and environmental factors. Comparable levels of acid detergent fiber (ADF) and ME were reported by Seyoum *et al*. (2007) and Getu *et al*. (2012) for natural pasture hay. The concentration of CP in molasses in our study aligns with Dawit *et al*. (2013), who reported a CP value of 3–4%. However, our findings contrast with previous research by Sani *et al*. (2016), which indicated a lower CP value (2%) in molasses. This disparity could be attributed to variations in molasses sources, processing methods, or analytical techniques employed between studies. The neutral detergent fiber (NDF) and *in vitro* organic matter digestibility (IVOMD) values of wheat bran observed in the current study are comparable with previous findings by Fekede *et al*. (2015), Ajebu *et al*. (2016), Dereje *et al*. (2017), and Terefe *et al*. (2021a).However, in the current study, higher dry matter (DM) and ash contents of wheat bran were observed compared to previous reports by Getu *et al*. (2012), Dawit *et al*. (2013), and Terefe *et al*. (2021b). Similarly, cotton seed cake (CSC) exhibited higher DM, ADF, and NDF contents compared to values reported by Dereje *et al*. (2017) and Terefe *et al*. (2021b). These differences could be attributed to variations in the sources of wheat bran and cotton seed cake, differences in processing techniques, or variations in the regions where the samples were obtained from. However, Geberemariyam *et al*. (2024) reported lower IVOMD and ME values in CSC. Additionally, Kasahun *et al*. (2012) and Ajebu *et al*. (2016) reported lower dry matter (DM), ash, and crude protein (CP) values in Noug seed cake compared to the current findings. This discrepancy suggests potential variability in the composition of Noug seed cake across different studies. Several factors could contribute to this variation, including differences in the geographical origin of the Noug seeds, variations in soil composition and environmental conditions affecting seed growth, differences in processing methods utilized to extract the seed cake, and variations in analytical techniques employed for nutrient analysis. Moreover, differences in the genetic makeup of the Noug plant varieties used for seed production could also influence the nutrient composition of the resulting seed cake. Thus, the observed differences underscore the importance of considering multiple factors when interpreting and comparing research findings across studies. Earlier studies have reported comparable proportions of DM and CP in the total mixed ration (TMR) which is consistent with the current finding (Shiriyan *et al*. 2011; Muhammad *et al*. 2012; Raja *et al*. 2013). However, Lailer *et al*. (2010), Pachauri *et al*. (2010), and Arto *et al*. (2014) reported lower fiber fractions in TMR, which could be attributed to variations in feed types and proportions used in TMR preparation.

Table 2: Experimental feed chemical composition

Heifers age		Hay	WB	CSC	NSC	M	Urea	Salt	TMRO	TMRR
4-6 Months	DM	93.5	92.1	94.2	93.2	74.5	-	-	92.1	89.9
	Ash	8.2	6.8	5.6	11.5	5.1	-	-	9.2	10
	CP	5.2	17	24	36.8	5	247	0	15.8	14.9
	NDF	65.6	49.6	42.7	37.8	-	-	-	46.6	63.2
	ADF	45.6	26.7	24.9	27.7	-	-	-	32.8	37.8
	ADL	9.4	3.9	6.3	4.4	-	-	-	6.5	7.2
	IVOMD	47.5	78.3	62.9	70.2	-	-		62.3	55.2
	ME	7.6	12.5	10.1	11.2	-	-	-	9.97	8.83
6-12 months	DM	94	93	93.5	92.9	75	-		93	91
	Ash	7.9	7.2	6.5	10.5	6	-	-	8.2	7.5
	CP	4.3	15	22	33	3	247	0	13	11.7
	NDF	54.3	50.6	39.6	39.4	-	-	-	45.2	52.1
	ADF	33.6	28	25	29.8	-	-	-	36.5	32.3
	ADL	8.7	3.5	5.7	4.1	-	-	-	5.5	6.4
	IVOMD	47.1	74.3	61.8	70.4	-	-	-	62.4	53.8
	ME	7.5	11.9	9.9	11.3	-	-	-	9.96	8.6
12-18 months	DM	93	93	92.1	92.9	74.8	-	-	88.9	90.2
	Ash	8	6.9	7	9.7	6	-	-	9.8	7.2
	CP	5.1	16.2	22.2	32.6	3.6	247	0	12.2	10.1
	NDF	61.3	47.8	41.7	34.8	-	-	-	52.3	48.7
	ADF	39.2	28.4	22	30.2	-	-	-	40.1	39.1
	ADL	10	4	6.2	5	-	-	-	4.4	5.7
	IVOMD	45.2	75	63	69.8	-	-	-	60.8	47.3
	ME	7.3	12	10.1		-	-	-	9.72	7.56

Except dry matter (DM), all values are represented on DM basis, CP=Crude protein;, NDF= Nutrient detergent fiber; ADF=Acid detergent fiber; ADL=Acid detergent lignin; IVOMD= Invitro organic matter digestibility; ME=Metabolizable energy; WB=Wheat bran; CSC=Cotton seed cake; NSC=Noug seed cake; M=molasses, TMRO =offered total mixed ration, TMRR=Refusal total mixed ration

Dry matter and nutrient intake

The dry matter and nutrient intake data are presented in Table 3. In the total mixed ration group (T2), intake levels of dry matter, organic matter, crude protein, and fiber fractions were notably higher ($P<0.05$) compared to separate feeding (T1). However, there was a significantly higher rate of feed refusal ($P<0.01$) in T1 compared to T2. The observed enhanced dry matter and crude protein intake in dairy calves fed on total mixed ration (TMR) is in line with the report by Shiriyan *et al*. (2011), DeVries and Gill (2012), and Dejene *et al*. (2017). However, the current result contradict those of Jalil *et al*. (2017) and Naik *et al.* (2009), who found no significant difference in feed consumption between TMR and separate feeding systems. According to observations by Miller and DeVries (2009), Maekawa *et al*. (2002), and Felton *et al*. (2010), the addition of water to TMR can deter intake and contribute to increased feed refusal in TMR. Restricting TMR availability to five hours per day altered the eating and rumination behaviours of lactating dairy cows, with *ad libitum* hay significantly affecting dry matter intake patterns, as noted by Heinrichs *et al*. (2021).

Table 3: Feed and nutrient intake in the experimental heifers

Intake (kg/calf/day)	T1	T2	SEM	SL
TDM	7.86	8.71	0.21	*
OM	7.36	8.32	0.13	*
CP	1.35	1.62	0.06	*
NDF	4.11	4.63	0.15	**
ADF	3.12	3.54	0.07	*
Refusal	2.05	1.32	0.40	**

.*=p<0.05; **= p<0.01, DM=Dry matter, TDMI= Total dry matter, CP= Crude protein, OM= Organic matter, NDF=Neutral detergent fiber, ADF=Acid detergent fiber, T1=Separate feeding; T2= Total mixed ration, SEM=Standard error of mean and SL=Significance level

Feed DM and nutrient digestibility

The apparent digestibility values for dry matter, organic matter, acid detergent fiber, neutral detergent fiber, and crude protein is presented in Table 4. Heifers fed total mixed ration (T2) showed significantly higher ($P<0.05$) digestibility of organic matter, neutral detergent fiber, and acid detergent fiber compared to heifers fed natural pasture hay and concentrate mixture separately (T1).The current finding is consistent with previous studies by Hundal *et al*. (2004), Khan *et al*. (2010), Raja *et al*. (2013), Jalil *et al*. (2017) and Terefe *et al*. (2021b) who reported that total mixed ration (TMR) has a significant effect on the nutrient digestibility in dairy cows, calves, and buffalo. However, there was no significant difference ($P>0.05$) in dry matter and crude protein digestibility between T1 and T2. However, studies by Bargo *et al*. (2002) and Dey *et al.* (2022) reported no significant variation in dry matter and crude protein digestibility between total mixed ration (TMR) and separate feeding in dairy cattle. Thorough mixing in a TMR promotes uniform microbial colonization, enhancing microbial action in the rumen and facilitating breakdown and fermentation of fibrous materials. Additionally, it maximizes surface area for enzymatic and microbial activity, enhancing access to substrates in NDF and ADF. Synergistic effects in a TMR promote efficient fiber digestion, aided by readily fermentable carbohydrates from concentrate.

Table 4: Apparent dry matter and nutrient digestibility in the heifers fed with total mixed ration and separate feeding

Parameters (%)	T1	T2	SEM	SL
DM	67.18	64.42	2.11	NS
OM	70.67	73.67	3.1	*
CP	73.64	71.99	2.16	NS
NDF	63.99	68.78	1.7	**
ADF	60.74	65.08	1.65	**

*p<0.05; ** p<0.01; NS= Non significance; DM=Dry matter, CP= Crude protein, OM= Organic matter, NDF=Neutral detergent fiber, ADF=Acid detergent fiber, T1=Separate feeding; T2= total mixed ration, SEM =standard error of mean, and SL=significance level

Daily weight gain and feed conversion efficiency

Heifers fed total mixed rations (TMR) (T2) demonstrated significantly higher (P<0.01) average daily weight gain, feed conversion efficiency, and protein conversion efficiency compared to those on separate feeding (T1). Throughout the growth period, heifers in T2 group exhibited greater weight gain than those on T1. The feed conversion efficiency of heifers in T2 was also significantly higher (P<0.001) than in T1 (Table 5). Calves on a TMR-based diet experienced enhanced daily weight gain due to higher nutrient intake and digestibility. Despite the absence of a significant difference (P > 0.05) in dry matter and crude protein digestibility between T1 and T2, the elevated daily body weight gain observed in TMR feed (T2) can be attributed to several factors. Firstly, the higher crude protein intake in T2 groups may have contributed to improved growth rates, as protein is essential for muscle development and overall growth. Additionally, enhanced digestibility of energy source nutrients such as acid detergent fiber (ADF) and neutral detergent fiber (NDF) in the diets could have provided a more efficient energy supply, supporting increased body weight gain. A higher intake and improved utilization of these fibrous components may have facilitated better rumen function and microbial activity, leading to enhanced nutrient absorption and utilization for growth. This finding is supported by Cavallini *et al*. (2023), who reported that higher daily body weight gain (618 g/day) in calves on a natural pasture based total TMR. Additionally, our results align with those of Nissanka *et al*. (2010), O'Neill *et al*. (2011), Shiriyan *et al*. (2011), and Cavallini *et al*. (2023), indicating that TMR positively impacts growth rate, rumen development, and nutrient intake balance in dairy calves and heifers. Similarly, Iqbal *et al*. (2019) and Terefe *et al*. (2021a) reported as dairy calves fed on a TMR diet improved daily body weight gain and feed efficiency. Offering TMR *ad libitum* to Holstein calves resulted in robust growth levels without compromising health effect (Spina *et al*. 2023) but Mitchell et al. (2020) stated that the transition of component feeds to TMR resulted in higher hay consumption, consequently lowering the intake of starter and overall dry matter. This, in turn, led to diminished weight gain and structural development. The observed greater feed and protein conversion efficiency in the case of TMR diet is consistent with findings of DeVries (2011), Muhammad *et al*. (2012), and Dejene *et al*. (2017).

Table 5: Feed efficiency and daily body weight gain of heifers under total mixed ration and separate feeding

Growth Parameters	T1	T2	SEM	SL
Initial live weights	90.4	90.4	0.0	NS
Final live weight(kg)	199.3	263.9	5.45	*
Mean of live weight gain(kg)	108.9	173.50	4.24	**
Average daily body weight gain(gram)	335.18	600.55	44.23	***
Feed conversion efficiency(DBWG:DDMI)	0.04	0.07	0.01	***
Protein conversion efficiency (DBWG:DCPI)	0.25	0.37	0.01	**

*=p<0.05; ** =p<0.01, ***=p<0.001; NS= Non significance, SL=significance level; T1=Separate feeding; T2= total mixed ration, DBWG=Daily body weight gain, DCPI=Daily crude protein intake, DDMY=Daily dry matter intake, SEM =standard error of mean and kg=kilogram

Reproductive performance

Heifers provided with a total mixed ration (TMR) (T2) showed significantly higher ($p<0.001$) weight at first service compared to heifers raised on separate feeding of natural pasture and concentrate (T1). Moreover, heifers in T2 group had shorter ($P<0.01$) ages at first service and first conception than those in T1. Additionally, heifers under T2 groups required fewer services per conception compared to T1 (Table 6). This result aligns with earlier studies by Coppock *et al*. (1981), Hamed *et al*. (2011), and Soren *et al*. (2013), which demonstrated that total mixed ration (TMR) is highly effective in enhancing nutrient consumption and improving reproductive and productive performance in dairy heifers. Feeding concentrate and fodder separately, as highlighted by Maekawa *et al*. (2002), increases the risk of ruminal acidosis due to inadequate nutrient supply, negatively impacting dairy cattle's reproductive and productive capabilities, and making them more susceptible to disease. Previous research by Muller *et al*. (2011), Hamed *et al*. (2011), and Siatka *et al*. (2017) also supports the positive effects of TMR on service per conception, age at first service and first conception in dairy heifers and cows. However, contrary findings were reported by Muller and Botha (2013), who found no effect of either TMR or separate feeding on inseminations per conception in dairy cows.

Table 6: Reproductive performance of heifers' fed total mixed ration and natural pasture hay and concentrate separately.

Parameters	T1	T2	SEM	SL
Weight at first service (kg)	199.3	263.9	10.48	***
Age at first service (months)	15.63	13.61	0.55	**
Age at first conception (months)	17.03	15.83	0.65	***
Number of services per conception	1.75	1.12	0.29	**

** =p<0.01; ***=p<0.001, SL=Significance level; SEM =Standard error of mean, kg=kilogram; T1=Separate feeding; T2= Total mixed ration

Partial budget analysis

The cost-benefit analysis of separate feeding and total mixed-ration feeding is presented in Table 7. In the total mixed ration (T2), significantly higher ($P<0.05$) total fixed cost, total revenue, gross margin, net margin, and marginal rate of return were observed compared to separate feeding (T1). Conversely, total variable cost was higher ($P<0.05$) in T1 than in T2. Total mixed ration (TMR) feeding showed a lower total cost of production for the calves. Similarly, previous studies by Soder and Rotz, (2003), Yi Zheng, (2013), and Soren *et al*. (2013) have highlighted that heifers and dairy cows fed a TMR can reduce production costs by enhancing daily feed conversion efficiency and generating higher profits. Research by Iqbal *et al*. (2019) demonstrated that feeding pelleted TMR containing 15% oat hay could reduce weaning age by five days and feed cost per unit gain by 14% without compromising growth performance and feed efficiency in crossbred calves under heat stress conditions. Similarly, Jahani-Moghadam *et al*. (2015) found that including alfalfa hay (10%) in the TMR diet could reduce the cost of production for Holstein calves

Table 7: Cost-benefit analysis of the heifers' fed total mixed ration and natural pasture hay and concentrate feed separately.

Variable cost ($)	T1	T2
Initial cost of calf	55.56	55.56
Feed cost	412.42	320.96
Labour (Transport &house cleaning)	33.83	33.82
Medication/Veterinary cost	5.33	3.11
Ropes	0.44	0.44
Plastics	0.22	0.89
Miscellaneous	11.11	11.11
TVC ($)	518.93	425.91
Total fixed cost ($)		
Local Chopper (Pole)	0.00	4.44
Feed trough	2.22	2.22
Water trough	2.22	2.22
Bucket/ '*joneya*'	1.33	1.33
Spade	1.11	1.11
Rakes	2.22	2.22
TFC ($)	9.11	13.56
TC=TVC+TFC	528.05	439.47
Return ($)		
Manure/ Dung Selling	58.00	63.22
Selling price of heifer after the experiment	560.67	623.89
TR ($)	618.67	687.12
GM	99.74	261.21
NM	90.62	247.65
MRR or CBR (TR:TC)	1.17	1.56

CBR= Cost-benefit; TVC=Total variable cost; TFC=Total fixed cost; GM=Gross margin; NM=Net margin; TR=Total revenue; TC=Total cost and MRR=Marginal rate of return, T1=Separate feeding; T2= Total mixed ration.

Conclusion

Feeding heifers a total mixed ration led to elevated dry matter intake, enhanced nutrient digestibility, improved feed efficiency, and increased weight gain. Consequently, employing a total mixed-ration feeding approach proves profitable and holds practical significance for dairy farming. However, additional research is warranted to thoroughly understand its long-term impacts on the health and reproductive performances of dairy heifers.

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Author Contributions

Geberemariyam Terefe and Getu Kitaw: Conceived and designed the experiments; Performed the experiments; Contributed reagents, materials, analysis tools, or data; Wrote and edit the paper. Ajebu Nurfeta, Getnet Assefa, Mesfin Dejene, and Mulugeta Walelegne: Analysed and interpreted the data; Contributed materials, analysis tools; Wrote and review the paper.

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