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Effect of feeding system on productive performance, nutrient digestibility, and economic return in Brahman crossbred cattle

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Abstract The results indicated that the different feeding systems for three groups of Brahman crossbred cattle, such as a separated feeding group I followed by dried concentrate, SF-RDC, a separated feeding group II, followed by wet concentrate, SF-RWC and a FTMR-R group, which was not significantly showed the impact on animal body weight (including weight gain and average daily gain) and feed conversion ratio of all groups in the overall period. However, the SF-RDC group had the highest feed cost per gain ($P<0.05$). The dry matter intake, measured in grams per kilogram of metabolic body weight, which was significantly higher in the FTMR-R group than in the other treatment groups. In contrast, the nutrient intake and digestibility in the cattle was not significantly differed among the groups. In the SF-RWC and FTMR-R groups, the net profit (%) was higher than in the SF-RDC group. It concluded that separate feeding of rice straw and dried concentrate may not be practical as it decreased the net profit percentage.

Keywords: Feeding regime, Feeding trial, Ruminant

Introduction

The beef cattle industry was always challenged to boost output while keeping costs under control. This was particularly true for feeding strategies that were sustainable and tried to maximize economic return, nutrient digestibility, and growth performance. People often used traditional feeding methods, such as decreasing or separating concentrate and roughage feeding, in an attempt to save money. However, Mohammad *et al.* (2017) pointed out that these methods typically lead to uneven feed consumption, lower weight gain, and varied meat quality. These techniques may result in lower feed prices, but they usually did not use energy and nutrients as well as they should, which eventually reduced

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production efficiency. Total Mixed Ration (TMR) was a widely used feeding method for ruminants, as it ensures a balanced nutrient intake in every bite. This method involved mixing roughage, concentrates, and supplements in appropriate proportions, which enhances digestion and nutrient utilization. As a result, animals maintain good health and achieve optimal productivity. However, despite its numerous advantages, TMR had certain limitations, particularly when using wet feed ingredients such as fresh cassava pulp, silage, or fresh corn plants. These materials were prone to spoilage if not properly stored and managed, which could compromise feed quality and potentially affect animal health.

Fermented Total Mixed Ration (FTMR) or fermented TMR was an innovative feeding approach designed to enhance the efficiency of ruminant nutrition by combining all essential feed ingredients into a single, well-balanced diet that undergoes fermentation before feeding. The fermentation process encourages the growth of beneficial microorganisms that enhance feed quality while reducing the risk of spoilage and nutrient loss (Nishino *et al.,* 2003). FTMR was particularly suitable for high-moisture feed ingredients, such as fresh forage, brewers' grains, and agricultural by-products, as the ensiling process helps preserve these materials, extending their shelf life and maintaining their nutrient value. This made FTMR a practical solution for utilizing perishable feedstuffs efficiently while minimizing feed waste. FTMR was especially beneficial for cattle production, as it improved feed intake, digestion, and overall growth performance (Cao *et al.,* 2009; Wang *et al.,* 2024). The fermentation process reduced antinutrient factors, increased microbial protein synthesis, and stabilized the feed, making it a practical solution for farmers aiming to optimize cattle nutrition with minimal wastage. Additionally, FTMR had been linked to improved rumen function, better weight gain, and enhanced feed efficiency, making it a promising strategy for sustainable livestock farming (Yuangklang *et al.,* 2004; Meenongyai *et al.,* 2017; Subepang *et al.,* 2019). However, the TMR feeding system required a chopper and mixer, which made it less practical for livestock farmers who continue to use the method of separately feeding roughage and concentrate.

Currently, the wider potential of TMR in beef cattle—especially Brahman crossbreds—remains largely unexplored, partly because many farmers lack the necessary resources and expertise (Sinclair *et al.,* 1989). Alternative feeding strategies that can improve production results while being commercially feasible and useful for a range of farm operations must thus be immediately investigated. Several studies investigated the effects of feeding systems on productive performance, but there still need to be significant gaps in understanding their broader impacts on long-term growth and economic return. In young bulls, Avilés *et al*. (2015) evaluated the effects of concentrate and wheat straw versus

TMR feeding on growth performance and carcass characteristics. TMR feeding improved the carcass yield and fatness, but there were no significant differences in daily weight gain, indicating that TMR may boost some production metrics but not necessarily improve growth. Liu *et al.* (2016) looked into different feeding orders, specifically whether cattle got roughage or concentrate first. They found that cattle fed TMR had higher daily gains and better ruminal development than cattle fed concentrate or roughage separately. However, Liu *et al.* (2016) documented no changes in the particle size distribution of rumen digesta. This showed that while TMR did improve some performance indicators, its effects on digestion need more research, especially in different breeds of cattle.

However, information regarding the testing of feeding systems in Brahman crossbred cattle on productivity and profitability when fed differently, remained limited too. This study aimed to examine the effect of feeding system on productive performance as following: nutrient digestibility, economical return, live body weight, live body weight gain, average daily gain, dry matter intake and nutrient intake (organic matter, neutral detergent fiber, acid detergent fiber, and ether extracts).

Materials and methods

This experiment was conducted at Aun village, Roiet province, Thailand from January 5 to June 12, 2021.

Animals and experimental design

Twenty-four Brahman crossbred steers weighed 200±55 kg (mean ± standard deviation). The animals were split into three nutrient treatments, and each treatment had eight replications. The experiment used a randomized complete block design. The treatments were as follows: I) separated feeding group I, cattle fed rice straw and dried concentrate (SF-RDC); II) separated feeding group II, cattle fed rice straw and wet concentrate (SF-RWC); and III) fermented total mixed ration (FTMR) group, cattle fed FTMR with rice straw as roughage (FTMR-R). Each animal was kept in a separate pen measuring 3.0 by 3.5 meters, ensuring they had unrestricted access to clean water. The cattle were provided an injectable vitamin AD_3E supplement (Phoenix, Belgium: vitamin A 300,000 IU, vitamin D_3 100,000 IU, and vitamin E acetate 50 mg; injected at 1 mL per 50 kg living weight) at the start of the experiment.

Experimental diet preparation and animal feeding

The experimental diet was specifically designed to meet beef cattle's nutrient requirements, with an average daily weight gain of 1.0 kg/day. It contained 13.3% crude protein and 10.4 MJ/kgDM of metabolizable energy (WTSR, 2010). As shown in Table 1, all feedstocks were purchased locally from marketplaces in Roiet province, Thailand. The 200-liter plastic silo tanks were filled with a prepared batch of 200 kg of fresh matter, either for fermented total mixed ration (FTMR) or wet concentrate (WC), after mixing it in a horizontal feed mixer. The tanks were kept outside for a minimum of 7 ensiling days. The dried concentrate was combined using a feed mixer machine and stored in plastic tanks. The animals were fed at 08:00 and 17:00 each day. The SF-RWC and SF-RDC groups received roughage and concentrate in the same dry matter ratio as the FTMR-R group.

Table 1. The ingredients of experimental diet

Items	Ratio			
	Roughage	Dried concentrate	Wet concentrate	FTMR
Ingredients (%DM)				
Rice straw	100	-	-	31.00
Fresh cassava pulp	-	-	37.68	28.00
Dried cassava pulp	-	37.68	-	-
Dried Cassava chip	-	8.12	8.12	6.60
Palm kernel meal	-	13.04	13.04	11.5
Soybean meal	-	25.36	25.36	12.40
Rice bran	-	13.26	13.26	8.65
Urea	-	1.23	1.23	0.95
Mineral	-	0.72	0.72	0.50
Premixed	-	0.58	0.58	0.40
Total	100	100.00	100.00	100.00

Data and sample collection

Animal weight and feed intake

Steers were weighed monthly and recorded in the morning (08:00), to determine body weight and metabolic body weight for each group. The offered feed was weighed daily and the animal fed after the refused feed was removed. The refused feed from the previous day was recorded daily. Feed intake was calculated as the difference between the amount of offered and the amount of refused feed.

Digestibility was analyzed using the acid-insoluble ash (AIA) marker technique, following the method of Van Keulen and Young (1977). Fecal grab samples (200 g/animal) were collected daily for 5 consecutive days before feeding, using rectal palpation. At the end of the sampling period, the samples were pooled to produce a composite sample for each animal. The offered feed, refused feed, and fecal samples were stored at −18°C until analysis.

At the conclusion of the experiment, all samples (offered feed, refused feed, and feces) were thawed, thoroughly mixed, and a 1% aliquot was oven-dried at 65 °C for 72 hours. The dried samples were then ground to pass through a 1-mm screen. Dry samples of feed and feces were analyzed for dry matter (DM), organic matter (OM), crude protein (CP), and ether extract (EE) according to AOAC (1995) procedures. Neutral detergent fiber (NDF), assayed with a heat-stable amylase and expressed inclusive of residual ash, as well as acid detergent fiber (ADF), also expressed inclusive of residual ash, were analyzed following the methods of Van Soest *et al.* (1991).

Production cost and economic return

The production cost and economic return were determined using equations (1) to (6), respectively:

cattle cost	=	initial live weight x animal price	(1)
feed cost	=	feed intake x feed price	(2)
management cost	=	Wages cost + housing cost + medicine cost + water cost + electric cost	(3)
total cost	=	cattle cost + feed cost + management cost	(4)
total income	=	final live weight x animal price	(5)
profit	=	total income (5) - total cost (4)	(6)

Statistical analysis

All data were analyzed using the general linear model procedure of SAS (1998) according to a randomized complete block design. The mean values were compared by Duncan's test. Unless otherwise stated, significant differences were P < 0.05.

Results

The growth performance

Result showed that the feeding system had not influenced on live weight, weight gain, average daily gain, and feed conversion ratio (Table 2). The SF-RDC group had the highest feed cost per gain whereas the costs for the other groups were not statistically significant differences (P > 0.05).

Table 2. Body weight, weight gain, and productive performance of cattle fed the experimental diet with different feeding

Items	Feeding			SEM	P –value
	SF-RDC	SF-RWC	FTMR-R		
Live weight (kg)					
Initial	209.8	201.1	200.1	5.09	0.3668
Final	345.8	343.1	345.6	9.82	0.7832
Weight gain (kg)					
Day 0 - 30	27.3	26.4	31.6	3.14	0.4678
Day30 - 60	37.4	33.4	37.1	3.06	0.5958
Day 60 - 90	40.9	43.3	39.3	4.31	0.8072
Day 90 - 120	32.5^{b}	39.0^{a}	37.5^{a}	1.17	0.0040
Overall	138.0	142.0	145.5	7.44	0.7788
Average daily gain (kg/day)					
Day 0 - 30	0.91	0.88	1.06	0.104	0.4676
Day30 - 60	1.25	1.11	1.24	0.102	0.5925
Day 60 - 90	1.36	1.44	1.39	0.144	0.8124
Day 90 - 120	1.08^{b}	1.30^{a}	1.25^{a}	0.039	0.0039
Overall	1.15	1.19	1.21	0.063	0.7786
Feed conversion ratio					
Day 0 - 30	5.19	4.64	4.68	0.542	0.7400
Day30 - 60	4.62	5.77	4.61	0.479	0.1723
Day 60 - 90	4.52	4.61	5.33	0.558	0.5444
Day 90 - 120	7.09^{a}	5.53^{b}	6.05^{b}	0.317	0.0113
Overall	5.12	5.04	5.06	0.215	0.9675
Feed cost per gain					
Day 0 - 30	54.00	44.55	41.80	0.498	0.2324
Day30 - 60	48.32^{ab}	55.10^{a}	41.22^{b}	4.198	0.0994
Day 60 - 90	47.14	43.78	47.66	4.513	0.8067
Day 90 - 120	74.28^{a}	53.99^{b}	54.51^{b}	3.837	0.0027
Overall	53.46^{a}	48.49^{b}	45.26^{b}	1.441	0.0044

$^{a\ b}$ Mean with different superscripts within columns significantly differed (P < 0.05), SEM = Standard error of mean

Feed intake and digestibility

The FTM-R group had the highest daily dry matter intake (g/kg $BW^{0.75}$) compared to the SF-RDC and SF-RWC groups. The treatments were not significantly influenced the overall nutrient intake or the digestibility (P > 0.05) in Table 3.

Table 3. Feed intake and digestibility of cattle fed the experimental diet with different feeding

Items	Feeding			SEM	P –value
	SF-RDC	SF-RWC	FTMR-R		
Daily feed intake					
Dry matter (kg)	5.89	5.83	6.08	0.155	0.5025
Dry matter (%BW)	2.12^{b}	2.18^{ab}	2.16^{a}	0.023	0.0082
Dry matter (g/kg $BW^{0.75}$)	86.13^{b}	86.83^{b}	90.51^{a}	1.145	0.0364
Nutrient intake (kg/day)					
Organic matter	5.52	5.29	5.47	0.238	0.7797
Crude protein	0.90	0.86	0.89	0.313	0.7784
Neutral detergent fiber	2.99	2.87	2.97	0.129	0.7737
Ether extracts	0.06	0.06	0.06	0.001	0.0991
Acid detergent fiber	1.99	1.91	1.98	0.050	0.5108
Digestibility (%)					
Dry matter	74.7	75.4	75.9	0.71	0.6461
Organic matter	77.1	79.0	79.0	0.58	0.1736
Crude protein	61.2	61.3	62.5	1.11	0.7965
Neutral detergent fiber	59.5	59.4	60.9	1.18	0.7298
Acid detergent fiber	49.1	49.2	50.1	0.80	0.4217

[a b] Mean with different superscripts within columns significantly differed (P < 0.05), SEM = Standard error of mean

Table 4. Production cost, income, and profit of cattle fed the experimental diet with different different feeding

Items	Feeding			SEM	P –value
	SF-RDC	SF-RWC	FTMR-R		
Total production cost (Baht)	29,216.70	27,758.80	27,398.70	962.679	0.1412
Breed cost (Baht)	20,975.00	20,112.50	20,012.50	509.603	0.3668
Feed cost (Baht)	$7,378.20^{b}$	$6,782.80^{a}$	$6,522.70^{a}$	225.159	0.0483
Total management cost (Baht)	863.47	863.47	863.47	-	-
Total income (Baht)[1/]	34,080.00	3,626.00	3,871.00	640.459	0.9462
Economic return					
Net Profit (Baht/head)	4,862.90	5,867.40	6,472.63	546.173	0.1458
Profit (Baht/day)	284.00	280.24	282.29	8.019	0.1459
Profit (%)	16.71^{b}	21.30^{a}	23.88^{a}	1.960	0.0415

[a b] Mean with different superscripts within columns significantly differed (P < 0.05), SEM = Standard error of mean

The production cost and economic return

It showed that there were not significantly differed in total product cost, total management cost, or profit (Baht/head and Baht/day) among the different feeding systems as seen in Table 4. The SF-RDC group recorded the lowest profit percentage as compared to the other groups (P<0.01).

Discussion

The study showed that all experimental groups constantly gained by about 1.2 kg/day, indicating that the cattle's nutrient needs were met. The nutrient requirements of beef cattle were affected by their breed, age, sex, and the amount of meat they had to produce. These things were very important in figuring out the right feed combinations to help animals grow and perform at their best (WTSR, 2010). These results agreed with Somboonchai *et al.* (2022), who reported that Brahman crossbred cattle weighing about 300 kg had an average daily gain ranging from 0.5 to 0.8 kg/day. Lee *et al.* (2021) also found that Hanwoo cattle with 300 kg of live weight did not grow at significantly different rates (0.8 kg/day) compared to the TMR feeding group (P<005) when they were fed different types of feed. However, TMR feeding techniques demonstrated a more comprehensive nutrient intake, improved animal output, fewer losses, and a reduction in the labor and time needed for livestock management, according to Karunanayaka *et al.* (2021). Ahn *et al.* (2021) report that Hanwoo cattle fed TMR gained on average 0.76 kg/day, a greater rate than the 0.64 kg/day average growth rate achieved by cattle fed on separated feed systems.

The feed cost per gain (FCG) in this study was similar to what Meenongyai *et al.* (2017) found: 45.9 baht/kg of meat production for Holstein-Zebu crossbred cattle fed FTMR and 48.9 baht/kg of meat production for Holstein-Zebu crossbred cattle fed TMR. In the present study, the FCG in the SF-RDC group was the highest. The higher price of dried cassava pulp in the feed formulation resulted in higher production costs compared to the SF-RWC and FTM-R groups, which offered more cost-effective alternatives. Utilizing abundant agricultural by-products offers a promising strategy for reducing production costs (Duangchan *et al.,* 2022).

Dry matter intake was a crucial factor in evaluating the productivity of beef cattle and acted as a forecaster of growth performance. A physical characteristic (such as their body type and organ function), the chemicals in their diet, their hormone levels, their health, and the local climate and surroundings all had an impact on how much DM they consumed (ARC, 1980; NRC, 2001). This investigation supported the findings of Avilés *et al.* (2015) and Moya *et al.*

(2011), who found no evidence of a significant difference (P > 0.05) in the amount of DM consumed by cattle fed TMR compared to those fed separately. In a similar vein, Hanwoo steers fed TMR or other diets showed no variation in their DM intake, according to Lee *et al.* (2021).

However, these results contrasted with Cooke *et al.* (2004) and Ahn *et al.* (2021), who reported higher DM intake in cattle on separate diets compared to TMR during the growing phase. According to Wongnen *et al.* (2009), fermentation did not alter the amount of DM intake in dairy cows fed TMR. However, Yuangklang *et al.* (2004) found that beef cattle fed fermented TMR had more DM intake than those that were fed TMR because fermentation made the feed palalibity better and made more nutrients available.

Nutrient intake did not differ significantly (P<0.05) in this study. This is similar to what Liu *et al.* (2016) found when they looked at CP intake and found that it did not differ significantly (P>0.05) between cattle on a TMR diet (1.09 kg/day) and those on separate feeding (1.16 kg/day). In Brahman cattle, the WTSR (2010) recommended 0.87 kg/day for a daily increase of 1.0 kg, which is similar to the average CP intake of 0.88 kg/day. The study's NDF intake, which showed no difference between TMR (4.1 kg/day) and separately feeding groups (3.7 kg/day), supported the findings of Lee *et al.* (2010). Wongnen *et al.* (2009) also found that the average daily intakes of 14.0, 2.2, 7.0, and 5.0 kg for OM, CP, NDF, and ADF, respectively, for dairy cows were not impacted by the fermentation methods. While Yuangklang *et al.* (2004) demonstrated that beef calves fed fermented TMR consumed more DM than those fed non-fermented TMR (P<0.05), this was most likely because the fermentation process enhanced the flavor of the feed and increased its nutrient availability.

The digestibility values provided information about feed quality by indicating the animals' effectiveness in utilizing nutrients (NRC, 2001). In this study, the nutrients digestibility did not change significantly (P > 0.05). This was consistent with the findings of Holter *et al.* (1997), who discovered that there were no significant differences (P > 0.05) between calves given a TMR diet and those fed a different system in terms of the digestibility of OM, CP, NDF, and ADF. These findings, however, differed from those of Li *et al.* (2003). They documented that Holstein steers fed TMR were better at nutrients digestibility (DM, OM, CP, NDF, and ADF) than steers fed a different diet, with scores ranging from 61-66% for DM, 59-69% for OM, 55-65% for NDF, and 50-59% for ADF. The increased digestibility observed in Li et al.'s study may be attributed to optimal rumen conditions and the balanced composition of TMR, which could enhance microbial activity in the rumen, leading to improved nutrient breakdown.

The nutrient digestibility values of FTMR in this study were similar to those reported by Kongphitee *et al.* (2018), who observed that the digestibility of DM, OM, CP, NDF, and ADF ranged from 56-74%, 61-78%, 60-64%, and 52-65%, respectively, in Thai native beef cattle fed FTMR with 10%, 30%, and 50% cassava pulp in the diet. Similarly, Subepang *et al.* (2019) found that Thai native beef cattle fed FTMR demonstrated greater digestibility values—71% vs. 61%, 73% vs. 64%, 62% vs. 56%, 53% vs. 43%, and 39% vs. 33%—for DM, OM, CP, NDF, and ADF in comparison to Charolais-crossbred cattle. Meenongyai *et al.* (2017) showed that there was no statistically significant variation ($P > 0.05$) in the nutrient digestibility of beef calves given FTMR compared to those fed TMR with grass serving as basal roughage source. DM, OM, CP, NDF, and ADF had digestibility values of 71% vs. 66%, 80% vs. 83%, 54% vs. 51%, and 45% vs. 44%, in that order. These results were in line with those of Wongnen *et al.* (2009), who found no difference variation in digestibility ($P > 0.05$) between dairy cows fed TMR and FTMR. A number of factors affect how differently digestibility varies. According to Cardenas-Medina *et al*. (2010), beef cattle belonging to the *Bos Indicus* group typically exhibit superior digestibility in comparison to their *Bos Taurus* group counterparts. On the other hand, Chaokaur *et al.* (2015) discovered that in Brahman cattle, digestibility drops as intake levels rise. This is probably because of a shorter rumen retention period, which reduces the chance of feed digestion. When Thai native beef cattle and Charolais crossbred cattle were fed 1.1M, 1.5M, or 2.0M (where M = maintenance metabolizable energy), it had little impact on their digestibility (Subepang *et al.,* 2019).

Feed prices could be decreased and livestock production efficiency increased by employing fermentation technology with inexpensive, large-scale agricultural byproducts like cassava pulp (Subepang *et al.,* 2019). Cassava pulp was highlighted as a crucial component of the experimental diet, which was created to satisfy the nutrient needs of developing Brahman crossbred cattle (weighing roughly 250–300 kg). Cassava pulps were a plentiful and affordable energy source. Cassava pulp's accessibility and affordability helped to lower production costs, which raised profitability.

This study concluded that different feeding systems did not significantly affect the body weight, weight gain, or feed conversion ratios of Brahman crossbred cattle. In the SF-RDC group, the feed cost per gain was the lowest, while economic returns were higher in the SF-RWC and FTMR-R groups. These findings suggested that the separate feeding of rice straw and dried concentrate may not be economically efficient. In tropical environments, adopting cost-effective feeding strategies is critical to improve cattle production.

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