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Effect of Two Types of Total Mixed Rations on Production Performances of Holstein Friesian Cows in Early Lactation

Research Article

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ABSTRACT

The milk production of high producing European dairy cattle breeds in tropical environment is not in satisfaction level. In general, cows develop negative energy balance at the early lactation resulting poor production performances. The aim of the study was to assess the effect of total mixed ration feeding systems (TMR) over conventional feeding system to increase the production performances of cows in early lactation. Napier (*Pennisetum purpureum*) based conventional feeding system (CFS) versus two different types of total mixed rations as TMR1 (with the same ingredients and same quantity in CFS) and TMR2 (16% dry matter of napier in TMR1 was replaced with legume and non-legume) were studied on production performances of 15 Holstein Friesian cows in early lactation (n=5). The highest average daily milk yield was observed in TMR2 fed cows (17.88±3.03 L/d) while the lowest was observed in CFS fed cows (12.23±0.88 L/d, P<0.0001). The percentage of average daily weight gain was differed (P=0.01) among the treatments (CFS=1.53%, TMR1=2.79%, and TMR2=4.32%). The body condition score of the cows fed with TMR1 and TMR2 was increased by 0.1 and 0.25, respectively at the end of the experimental period whereas it was unchanged in the cows fed with CFS. Results revealed that feeding of TMR for Holstein Friesian cows in early lactation is a better way to achieve increased milk production with a better body condition in the tropics. TMR consisted of legume and non-legume fodder was more efficient.

KEY WORDS conventional feeding system, early lactation, legume, milk yield, total mixed ration, weight gain.

INTRODUCTION

The main objective of rearing a milking herd is getting high milk yield, which is the key component of an economical dairy farm. The average daily milk production of locally born Holstein Friesian calves in early lactation has been reported as 12.2 L/d under conventional separate feeding of feed ingredients in Sri Lanka. In contrary, Kabuga (1991) reported that average milk yield of a farm born Holstein Friesian cow was 18.7 kg/d under tropical environment. Hence, there is a possibility to increase milk production of Holstein Friesian dairy cows under tropical environment. The economic value of milk is mainly depending on quantity and composition (milk fat (F), solid non-fat (SNF), and exceptionally total solids (TS) and mineral or milk ash content (A)). Therefore, it is important to maintain milk composition components in neediness to the product requirements.

Greater demand for energy and low dry matter intake of transition cows from pregnancy to early lactation lead to the state of negative energy balance (NEB) (Hayirli *et al.* 2002). The state of NEB results, reduction of body condition and milk production and increment of the possibility of metabolic disorders in cows (Kim and Suh, 2003). As a consequence of NEB, cow used to mobilize stored body fat during early lactation. Therefore, body weight lose can be seen. During this period, cows intake more dry matter to compensate the negative energy balance.

Body condition scoring (BCS) has been considered as the most practical method to access the changes in energy reserves (Bewley and Schutz, 2008). Assessment of BCS is a tool for identifying productive and reproductive performances, health status, animal well-being and overall farm productivity (Bewley and Schutz, 2008).

Further, the changes in BCS at calving and early lactation has an influence on animal health and reproduction. Hence, at early lactation, maintenance of BCS, reduce the loss of BCS or recover the lost BCS at higher rate vital for optimum milk production, reproductive efficiency (Bewley and Schutz, 2008) and profitability.

Diet of early lactating cows should be formulated to maintain body condition while maximizing milk yield. Many nutritional strategies have been deployed to reduce the severity and occurrence of metabolic disorders, aiming the improvement of production performances of early lactating dairy cows.

Total mixed ration feeding is one of such strategies that has been reported dairy cattle management. Previous research reported that TMR feeding system resulted in the highest total dry matter intake and milk production in comparison to grazing (Bargo *et al*. 2002). In TMR feeding, each mouthful contains same feed materials which results in fewer digestive disorders in dairy cows (Schingoethe, 2017).

Reducing forage particle size to an effective level may increase dry matter intake (DMI), digestibility, concentrations of rumen total volatile fatty acids (VFA) and may also reduce feed bunk sorting behavior of dairy cattle (Heinrichs *et al*. 1999).

Further, protein rich feed ingredients are added to balance low protein roughages, which improves the microbial activity and consequently they attack the crude fiber more vigorously (Gupta *et al.* 1970). Moreover, feeding of diets with high protein content resulted in higher organic matter and fibre digestibility in cows (Doreau *et al*. 1990; Belanche *et al*. 2012). Therefore, the objectives of the current study were to evaluate the effect of two different types of TMR experimental diets on the milk yield and composition [Milk fat (F %), solid non-fat (SNF %), total solid (TS %) and Ash (A %) content] of Holstein Friesian cows in early lactation in comparison to Napier based conventional feeding system (CFS), and to determine the variation of body condition score and body weight in the cows during the experimental period in three different treatments.

MATERIALS AND METHODS

This study was carried out at the Bopatthalawa farm which was managed by the National Livestock Development Board, Sri Lanka (Elevation 5000 ft). The temperature varied from 10 to 32 ˚C, with the rainfall of 300 mm/month and the relative humidity of 83-89% during the experimental period (July-August 2015).

Fifteen Holstein Friesian cows in early lactation (average live weight=467.7±45.8 kg, days in milk (DIM)= 53.37±18.14 days, parity=2.5±0.5, average daily milk yield (ADMY)=11.08±1.71 L/d) were selected for the feeding experiment.

Milk composition of selected cows were analysed before commencement of the experiment (Table 1) and were used as the baseline data to calculate nutrient requirements for milk production. Nutrient requirements of cows were calculated for targeted 18.5 L/d milk production (Kabuga, 1991) and 3.5% of milk fat content according to the NRC (2001) recommendations. The calculated nutrient requirement of cows for both maintenance and milk production are presented in Table 2.

The cows were randomly allocated to one of three treatments as CFS, TMR1 and TMR2 (n=5 each treatment). The CFS diet was consisted with Napier, brewer's grain and concentrate and each ingredient in diet were fed separately as in conventional feeding system practice in the farm. Cows in TMR1 were fed with the same diet as CFS, but grass was chopped and mixed with other ingredients as a total mixed ration.

The diet of TMR2 was consisted of Napier, brewer's grain, concentrate as in TMR1, but 16% of dry matter in TMR1 diet was replaced by legumes and non-legumes (LANL). The LANL was composed of 41 % of wild sunflower (*Tithonia diversifolia*), 25% of alfalfa (*Medicago sativa*), 8 % of white clover (*Trifolium repens)* and 26% erythrina (*Erythrina indica*) in dry matter, basis which were the available high protein containing plant materials in the farm.

The chemical compositions of feed ingredients, composition of LANL unit and ration composition are shown in Tables 3, 4 and 5, respectively. All the experimental cows were reared in a same barn and separate feeding bunks were provided for each treatment.

Each animal had *ad libitum* access to feed. One week was allocated as the acclimatization period for the ration and experimental was carried out for another six weeks (42 days) of period. Cows were fed four times a day at 03:00 hrs, 10:00 hrs, 15:00 hrs, and 18:00 hrs, and were milked at 03:00 hrs and 15:00 hrs. Milk samples were collected in weekly basis in the evening by using portable milking machine and analyzed for milk composition (total solids, density, fat) at the laboratory of Livestock Production, Faculty of Agricultural Sciences, Sabaragamuwa University of Sri Lanka.

Table 1 Milk composition of the selected cows used as baseline parameters

Treatment	Number of animals	Fat %	Solid non-fat %	Total solid %	Mineral %
CFS	5	3.4	8.65	11.95	0.61
TMR1	5	3.4	8.72	12.12	0.59
TMR2	5	3.5	8.67	12.07	0.62

CFS: conventional feeding system; TMR1: total mixed ration (similar ingredients as CFS) and TMR2: 16% of dry matter in TMR1 replaced by legumes and non-legumes.

Table 2 Nutrient requirements of an experimental cow for maintenance and production of targeted 18.5 L/d milk production and 3.5% milk fat

Nutrient	DM	CP	TDN	Ca	P
Requirement (kg/cow/d)	13.94	1.962	9.19	0.355	0.237

DM: dry matter; CP: crude protein; TDN: total digestible nutrients; Ca: calcium and P: phosphorous.

Table 3 Nutrient compositions of feed ingredients used in diet formulation

Ingredient	DM %	Nutrient compositions (Dry matter basis)						
		CP %	DCP %	EE %	CF %	Ca kg/kg	P kg/kg	TDN %
Napier (Marshall and Bredon, 1963; Palafox *et al*. 1961)	21	9.1	6	1.2	29	-	-	55
Commercial concentrate (Nissanka *et al*. 2010)	89.01	15.24	11.43	3.74	13.25	0.003	0.003	73.45
Brewer's grain (Nissanka *et al*. 2010)	21.71	18.02	13.51	3.27	11.25	-	-	79.17
Wild sunflower (Chandrasiri *et al.* 1987)	14.50	23.9	16.2	2.5	-	1.53	3.5	56
Erythrina (Chandrasiri *et al.* 1987)	22.65	25.45	19	4.21	-	1.3	2.6	48
Alfalfa (Ranjhan, 2001)	18	21.30	16.4	1.4	29.40	-	-	55.9
White clover (Ranjhan, 2001)	18	17.4	-	-	-	-	-	59.2

DM: dry matter; CP: crude protein; DCP: digestible crude protein; EE: ether extract; CF: crude fiber; Ca: calcium; P: phosphorous and TDN: total digestible nutrients.

Table 4 Compositions of legume and non-legume unit used in TMR2 to replace 16% of dry matter of TMR1

Feed ingredient	Composition				
	FM (kg)	DM (kg)	(Dry matter basis)		
			CP (kg)	TDN (kg)	Contribution (5)
Erythrina	20	4.53	1.02	2.175	41.0
Wild sunflower	20	2.9	0.693	1.624	26.0
Alfalfa	15	2.7	1.501	0.468	25.0
White clover	5	0.9	0.539	0.156	8.0
Total	60	11.03	3.753	4.423	100

FM: fresh mater; DM: dry matter; CP: crude protein and TDN: total digestible nutrient.

Table 5 Ration compositions of CFS, TMR1, TMR2 for targeted 18.5 L/d milk production and 3.5% fat content

Treatment		DM (kg)	Composition (Dry matter basis)				
			CP (kg)	TDN (kg)	Ca (g)	P (g)	CS (g)
CFS/TMR1 (N=5 each)	Brewers Grain	1.085	0.196	0.859			
	Concentrate	3.560	0.544	2.599			
	Napier	10.080	0.917	5.544			
	Total	14.725	1.657	9.002	8.5	3.6	20
TMR2 (N=5)	Brewers Grain	1.085	0.196	0.859			
	Concentrate	3.560	0.544	2.599			
	Napier	7.570	0.698	4.355			
	LANL[2]	2.206	0.467	1.166			
	Total	14.421	1.906	8.980	8.5	3.6	20

DM: dry matter; CP: crude protein; CS: common salt and TDN: total digestible nutrient
CFS: conventional feeding system; TMR1: total mixed ration (similar ingredients as CFS) and TMR2: 16% of dry matter in TMR1 replaced by legumes and non-legumes.
LANL: legume and non-legume.

Milk density (D) was measured by using lactometer (Omsons Lactometer, TechnoConcept India Pvt. Ltd., India), gerber test was done to measure the fat content and then solid non-fat and total solid were interpreted by using Richmond Formula as follows:

Solid non-fat= 0.25 × density + 0.22 × fat + 0.72
Total solid= fat + solid non-fat

Ash content was determined by combustion of samples in Muffle Furner at 550 ˚C for three and half hours. Body weight of the cows was recorded on the first day of the experiment and then on the final day by using fixed cattle weighing balance (Cardinal Livestock Scales, USA). The BCS of the cows were ranked by an experienced veterinary surgeon in the farm at the first and last days of experiment. Body condition scouring system used was with 1 to 5 scale with interval points 0.25 (Ferguson *et al.* 1994). Daily milk yield of cows recorded individually. Average daily milk yield (ADMY) of individuals were calculated in weekly basis.

Statistical analysis

Statistical analyses were conducted using SAS 9.4 software (SAS, 2003). Analysis of variance was performed for average daily gain, ADMY, BCS and milk composition considering the treatment as a fixed effect at confidence level of 0.05. Means separation was conducted by the Duncan's Multiple Range test.

RESULTS AND DISCUSSION

Average daily milk yield (ADMY)

Average daily milk yield was greater (P<0.0001) in TMR2 cows compared to TMR1 cows and CFS cows during the overall experimental period. Average daily milk yield of cows did not affect (P=0.0635) by the treatment during the first week of the experiment. Cows fed with TMR2 had a greater (P=0.0135) ADMY at the second week of experiment than CSF fed cows. However, ADMY of TMR1 cows did not differ (P>0.05) with both TMR2 and CFS. At the third week, ADMY of TMR2 cows was greater (P=0.0031) than both CSF and TMR1 cows. The ADMY of TMR2 cows was higher (P=0.007, P=0.0004, P=0.0002, respectively for fourth, fifth and sixth week) from week four to six compared to both TMR1 and CSF cows.

The ADMY of the CFS cows was gradually increased up to fourth week (from 11.37 to 12.68 L/d of ADMY), and then slightly decreased. The same trend was observed in TMR1 cows, but the ADMY of TMR1 was higher (P<0.05) than CSF from the third week. However, ADMY of TMR2 cows was increased at slightly higher rate until week four (1.796, 1.104, 0.662 L/d, during the second, third and fourth week, respectively) and then there was a slow rate of increment (0.366, 0.254 L/d, during fifth and sixth week, respectively) until the end of the experiment (Figure 1).

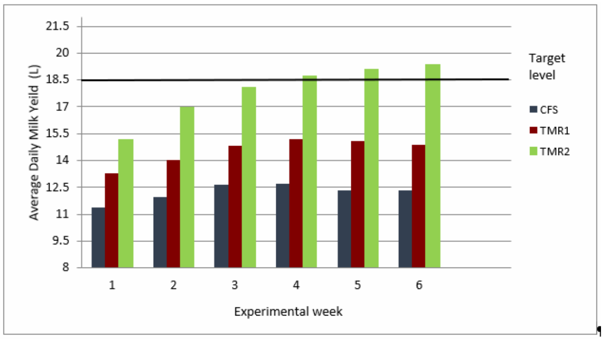

Figure 1 Average daily milk yield of the treatment groups in weekly basis
CFS: conventional feeding system; TMR1: total mixed ration (similar ingredients as CFS) and TMR2: 16% of dry matter in TMR1 replaced by legumes and non-legumes

The rations were formulated to reach the target of 18.5 L/d/cow milk production which was reported in Holstein Friesian cows born and raised in tropical conditions (Kabuga, 1991). Cows fed TMR2 reached to targeted milk production at the fourth week and maintained their milk production over the targeted value during the fifth and sixth weeks of the experiment. Although TMR1 cows had higher milk production compared to CFS, they did not reach the targeted daily milk production of 18.5 L. Milk production of cows during the first ten weeks has been reported to be higher in dairy cows fed TMR diet compared to a ryegrass-based pasture grazed cows (O'Neill *et al.* 2011). Further, Holter *et al.* (1977) has reported that mixed ration feeding resulted in 4% higher milk yield per unit intake of diet than the separate feeding of ingredients. Sorting behavior of cows has been reported by Leonardi and Armentano (2003), and cows sort small feed partials against longer forage particles. The highly palatable small feed components could be sorted against the long forage particles by CFS cows. The greater milk yield of TMR fed cows could be attributed to intake of uniform diet composition which avoid the voluntary selection of dietary ingredients offered separately (Holter *et al.* 1977; Mohammad *et al.* 2017). Hence, the both TMR1 and TMR2 fed cows were reported with higher milk yield compared to the CFS cows. However, the quantity of refused feed was not measured in the current study.

The CFS and TMR1 rations were composed of same ingredients in same quantities. Apparent digestibility of each ration could be the same for CFS and TMR1 rations except the effect of mixing of ingredients. Hence, ingested nutrients could be effectively utilized for milk production in TMR1 cows compared to CFS cows. In addition, selection of ingredients based on preference could be resulted in imbalance of ingested nutrients (DeVries *et al.* 2005), could lead to a lower milk production in CFS cows than cows fed TMRs.

Further, the rumen microbial community of dairy cows, particularly bacteria and archaeal, is affected by the diet (TMR *vs*. pasture diet) (De Menezes *et al.* 2011). The variation of rumen pH is less due to uniform feed in the rumen when cows were fed with TMR than the feeding roughages and concentrate separately (Molle and Landau, 2017; Beigh *et al.* 2017). Feeding of TMR stabilize the rumen fermentation and improves the nutritive utilization efficiency (Beigh *et al.* 2017). Further, milk production of cows declined as a consequence of low ruminal pH that reduces the dry matter intake, fiber digestibility and microbial yield (Allen, 1997). Thus, variations in rumen microbial community, rumen fermentation and efficient nutrient utilization could be the reasons for the difference in the milk production of CFS and TMR fed cows in the current study. Further, energy expenditure for eating and rumination reported to be higher for cattle fed more fibrous feed and un-chopped roughages (Susenbeth *et al.* 1998), consequently, less energy available for maintenance and production. Hence, TMR fed cows could be wasted less energy for rumination compared to the CFS and resulted in higher milk production.

The crude protein content of the TMR2 ration (13.21% DM basis) was higher than both CFS and TMR1 rations (11.25% DM basis) which had similar protein content. This is due to the inclusion of legume and non-legume in the TMR2 ration. Milk yield of dairy cows reported to be increased with the increment of crude protein content of diet to 17.5% by supplementation of soybean and cottonseed meal and milk production was affected by the source of crude protein (Imaizumi *et al.* 2010). Organic matter fermentation (*in vitro)* has been found to be affected by the crude protein and neutral detergent fiber content of the TMR (Boguhn *et al.* 2006).

The sensitivity of cellulolytic bacteria to nitrogen shortage suggested to be negatively affecting on the fiber digestion of the rumen (Belanche *et al.* 2012). Consequently, it reduces the milk production of dairy cows when fed with low crude protein containing diets (Belanche *et al.* 2012). Hence, in the present study cows fed TMR2 which were fed with high protein containing diet could had efficient organic matter digestion than CFS and TMR1 cows resulting in higher milk production. During the experimental period of 6 weeks, there was no significant difference (P=0.0725) in milk fat percentage among the three treatment groups (Figure 2). The average milk fat percentage of the CFS, TMR1 and TMR2 were 3.40%, 3.47%, and 3.32%.

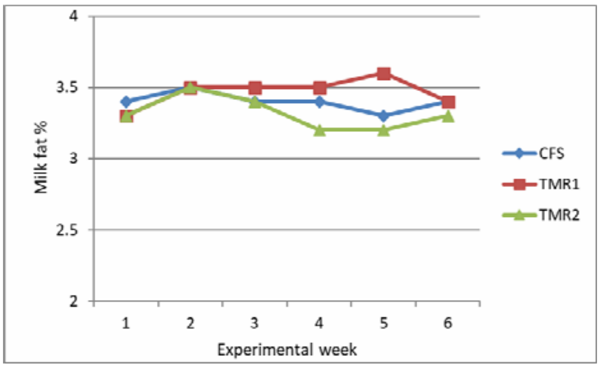

Figure 2 Fat content of milk
CFS: conventional feeding system; TMR1: total mixed ration (similar ingredients as CFS) and TMR2: 16% of dry matter in TMR1 replaced by legumes and non-legumes

Feeding rations with low in fiber and with short particle size will decrease chewing activity, salivary buffer secretion, ultimately lowering rumen pH, rumen acetate production and milk fat percentage (Kononoff and Heinrichs, 2002).

Total mixed ration feeding could avoid the small particle sorting behavior of cows. Thus, TMR1 cows could had a numerically higher fat content in the milk compared to CFS cows.

However, inclusion of legumes and non-legumes could reduce the fiber intake as 16% of Napier was replaced by LANL unit. Further, ADMY of TMR2 cows higher than other two treatments. Hence, those could be resulted in low milk fat content in TMR2 fed cows.

Solid non-fat (SNF) consists with proteins, lactose, minerals, acids and enzymes of milk. The SNF percentage of cows during the experimental period was higher (P=0.0385) in TMR2 compared to TMR1. However, SNF percentage did not differ (P>0.05) in between CFS and

TMR2 or TMR1 (Figure 3). The average SNF percentage of treatment groups were 8.65, 8.53 and 8.7 for CFS, TMR1 and TMR2, respectively (Figure 3).

The average total solids (TS) content of treatment groups were 12.06%, 12.0% and 12.02% for the CFS, TMR1 and TMR2, respectively and did not differ (P=0.3650) among the treatment groups (Figure 4). The average ash contents of treatment groups were 0.61%, 0.60% and 0.63% for CFS, TMR1 and TMR2, respectively and were differed (P=0.0120) among the treatments (Figure 5). Ash content was higher (P<0.05) in TMR2 cows compared TMR1 and CFS cows.

TMR modified with legume and non-legume sources (TMR2) was more effective in the ADWG in Friesian cows within early lactation than TMR1.

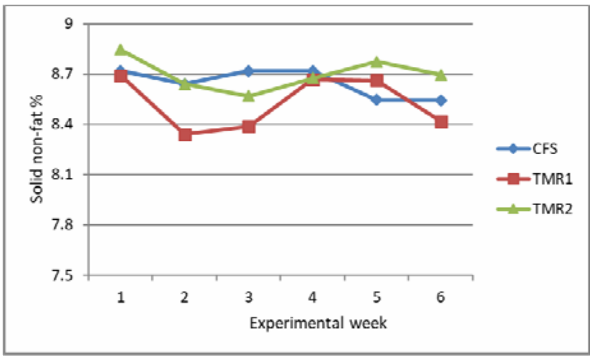

Figure 3 Solid Non-Fat content of milk
CFS: conventional feeding system; TMR1: total mixed ration (similar ingredients as CFS) and TMR2: 16% of dry matter in TMR1 replaced by legumes and non-legumes

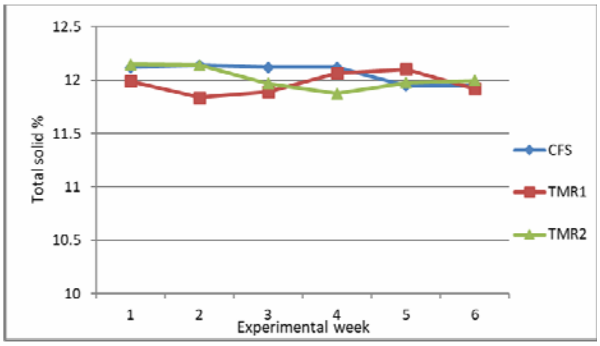

Figure 4 Total Solid content of milk
CFS: conventional feeding system; TMR1: total mixed ration (similar ingredients as CFS) and TMR2: 16% of dry matter in TMR1 replaced by legumes and non-legumes

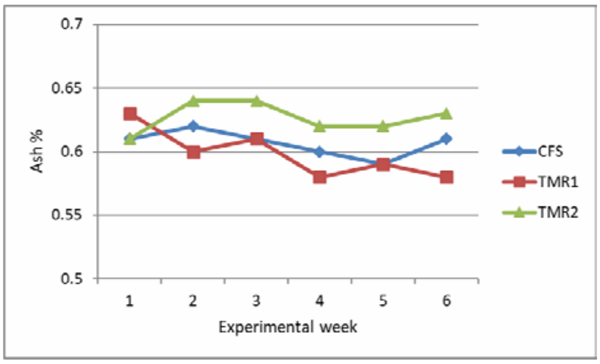

Figure 5 Ash content of milk
CFS: conventional feeding system; TMR1: total mixed ration (similar ingredients as CFS) and TMR2: 16% of dry matter in TMR1 replaced by legumes and non-legumes

The weight changes positive for CFS, TMR1 and TMR2 (166.7±65.2, 309.5±135.7 and 690.5±176.6 grams per day respectively). The weight changes as a percentage of cow's initial live weight were significant (P=0.0148).

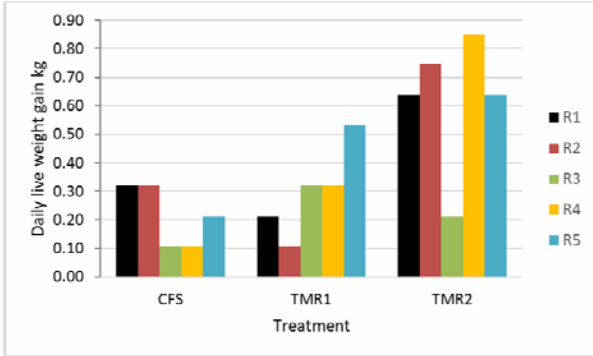

Figure 6 Daily weight gain of the experimental cows (R1, R2, R3, R4 and R5 are the replicate cows)
CFS: conventional feeding system; TMR1: total mixed ration (similar ingredients as CFS) and TMR2: 16% of dry matter in TMR1 replaced by legumes and non-legumes

It was 1.53%, 2.79% and 4.32%, respectively for CFS, TMR1 and TMR2 fed cows (Figure 7).

Negative energy balance is considered a physiological phenomenon in high-yielding dairy cows in early lactation (Goff and Horst, 1997). In early lactation, metabolic and endocrine changes drive the mobilization of body fat and skeletal muscle breakdown and direct the absorbed metabolites to the mammary gland to provide adequate substrates for milk synthesis. Practically all cows undergo a state of negative energy balance in early lactation and eventually recover from this state with dry matter intake (Jorritsma *et al.* 2003).

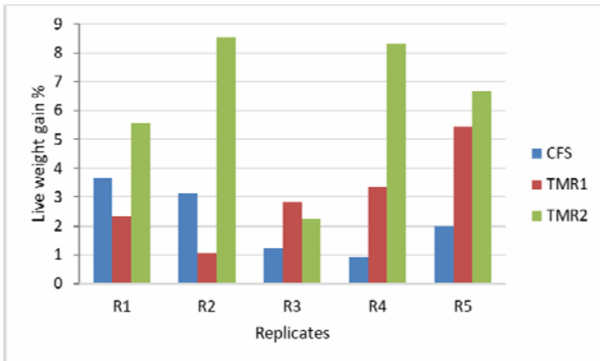

Figure 7 Live weight gain of experimental cow's as a percentage of the initial live weight
CFS: conventional feeding system; TMR1: total mixed ration (similar ingredients as CFS) and TMR2: 16% of dry matter in TMR1 replaced by legumes and non-legumes

The findings stand in contrast with those reported by Goff and Horst (1997). In the current study all the cows were gained live weight indicating the positive energy balance during the experimental period (Figure 6). Poncheki *et al.* (2015) reported that cows reached to the lowest body weight approximately 35 days after calving. Body weight recovery of Holstein cows reported to initiate at 30-33 days post-partum regardless of parity (Sakaguchi, 2009). The experimental cows were 53.27 ± 18.14 days in milk at the start and the last body weight was recorded at the end of six weeks of experimental period. Therefore, cows may stabilize the body weight after parturition when included in the experiment. The observed result was agreed with the previous studies (Garnsworthy and Topps, 1982; Ruegg and Milton, 1995; Heuer *et al.* 1999). The BCS of CFS cows did not differ throughout the 6 weeks of experimental period. However, BCS of TMR1 (0.1) and TMR2 (0.25) were changed during the experimental period. The change of BCS of each replicate cow was shown in Figure 8.

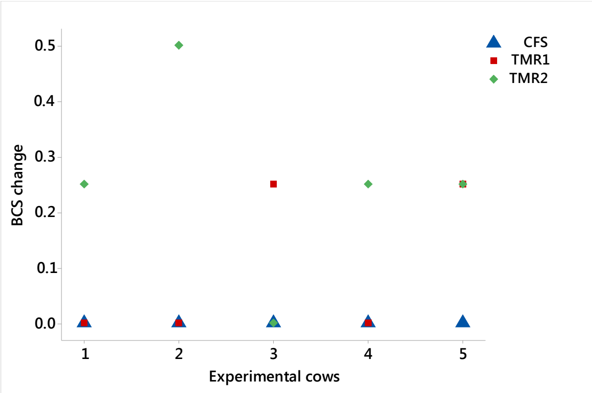

Figure 8 The change of BCS of the cows during the six weeks of experimental period
CFS: conventional feeding system; TMR1: total mixed ration (similar ingredients as CFS) and TMR2: 16% of dry matter in TMR1 replaced by legumes and non-legumes

The dairy cow relies on a combination of body reserves and available nutrients from feed to meet the demands of milk production. Up to one-third of the total milk solids produced in early lactation is produced from body tissue reserves (Bauman and Currie, 1980). The cows in the current experiment have gained live weight, which suggest that they could use less body reserves for milk production and maintenance, where excess nutrients deposited in the body. It has been reported live weight loss in early lactation was tended to reduce in a feeding system which provide mixed dietary ingredients (Phipps *et al.* 1984). O'Neill *et al.* (2011) also reported that BCS and live weight of TMR fed cows were higher than the cows had a grass feeding system in ealry lactation.

CONCLUSION

The TMR1 resulted in higher average daily milk yield (14.56±1.74 L) than the CFS (12.23±0.88 L). Inclusion of legume and non-legume fodder with replacing of Napier grass by 16% DM basis was more efficient on average daily milk yield (17.88±3.03 L). The milk composition was not significantly different among the three treatment groups except solid non-fat and ash contents. The percentage of ADWG of milking cows in early lactation was the highest in the TMR2 fed group (4.32%) in comparison to CFS (1.53%) and TMR1 (2.79%). BCS was slightly increased in TMR1 and TMR2 fed cows. Therefore, there is a possibility of resulting more milk production and better BCS in TMR fed Holstein Friesian cows in early lactation in the tropics. TMR consisted of legume and non-legume fodder was more efficient.

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