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Carryover effects of varying hay concentration on the transition to silage-based feeding of weaned dairy calves

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Abstract

Objectives of the experiment were to determine effects of dietary hay concentration in a dry total mixed ration and its carryover effects on intake, growth performance, faecal score, and feed efficiency of weaned dairy calves. Eighteen Friesian × Jersey weaned calves (n = 6 calves/treatment) were randomly assigned to three rhodes grass hay treatments (RG13, RG26, and RG39). The experimental diets were rhodes grass hay-based total mixed rations containing 13%, 26%, and 39% chopped hay on a DM basis. The experiment had two phases of four weeks each. In phase 1 (weeks 1–4), weaned calves were fed RG13, RG26, or RG39. Then, in phase 2 (weeks 5–8), all calves were shifted to a maize silage-based diet. All the diets were iso-nitrogenous and were fed ad libitum. Calves were housed in individual pens and had free access to water and feed. Average daily gain and daily dry matter intake were analysed as repeated measures, whereas bodyweight and feed efficiency were analysed using one-way ANOVA. In phases 1 and 2 dry matter intakes were similar. Growth rate decreased linearly with increasing concentration of hay in phase 1. Overall, daily dry matter intake, average daily gain, change in body condition score and structural measurements were not affected by dietary treatments. However, overall feed efficiency was improved for calves fed RG26 compared with RG13 and RG39. Thus, feeding a moderate level of hay had positive impacts on the transition to a silage-based TMR.

Keywords: dietary transition, total mixed ration, intake, growth, feed efficiency, body condition score, faecal score
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Introduction

Growing calves experience a dietary transition from milk and starter to a forage-based diet. The transition period can be stressful if not managed properly, resulting in high morbidity and mortality, and poor growth rates in dairy calves (Drackley, 2008),); whereas a smooth weaning transition increases ADG and reduces the incidence of morbidity in weaned calves. Hay is an important component of a calf ration that is conventionally fed after weaning, in which concentrate and long hay are offered separately to calves. Feeding a TMR has benefits over conventional feeding in terms of weight gain (Nissanka *et al.*, 2010).

Rumen musculature development and capacity are influenced by the physical stimuli provided by the bulk of the ingested material (Beharka *et al.*, 1998). In growing calves, forage provides bulk in the rumen and thus promotes rumen musculature and helps to maintain the integrity of the rumen epithelium (Beharka *et al.*, 1998; Beiranvand *et al.*, 2014). The inclusion of hay in diets of young calves increased intake and improved feed efficiency (FE) by altering the rumen environment (Coverdale *et al.*, 2004). However, a higher inclusion level of forage in a total mixed ration (TMR) decreased average daily gain (ADG) in calves (Hill *et al.*, 2008). Similarly, Hill *et al.* (2009) showed that ADG and dry matter intake (DMI) declined as roughage increased in the ration of young calves.

Limited information is available on the performance of weaned dairy calves that are shifted from a dry hay-based TMR to a silage-based TMR. Therefore, the objective was to determine the effects of dietary transition on post-weaning intake, growth performance, structural development, faecal consistency and FE in weaned dairy calves.

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Materials and Methods

The experimental procedures were approved by the Animal Care and Use Committee of UVAS (protocol no. 1246/ 21-11-2017). Eighteen crossbred Friesian × Jersey male calves that had been weaned at 60 ± 2.0 days old, weighing 71.6 ± 8.6 kg, were randomly assigned to three dietary treatments (n = 6 calves/treatment). Treatments consisted of i) RG13, which contained 13% Rhodes grass (RG) hay in TMR on DM basis); ii) RG26 (26% RG hay), and iii) RG39 (39% RG hay). All diets were iso-nitrogenous and fed once daily at 08:00. The total duration of the experiment was eight weeks, including two phases of four weeks each. During phase1 (1–4 week), calves were offered RG13, RG26, and RG39 diets according to their treatments. In phase 2 (5–8 week) all calves were shifted to a maize silage-based TMR. Calves were housed in individual pens of 1.5 m^2 and bedded with sand.

During phase 1 fresh TMR was mixed manually and fed ad libitum individually once a day at 08:00. The orts were collected daily before feeding, and feed was adjusted to ensure 10% of refusal (Table 1). In phase 2, maize silage and hay-based TMR was formulated, and a similar feeding routine was followed from week 5 to 8 (Table 2). Water was available ad libitum throughout the experiment.

Table 1 Ingredient and nutrient composition of hay-based total mixed rations (dry matter basis) fed to crossbred calves from week 1 through week 4 post-weaning

Ingredients (g/kg of DM)	Treatments[1]			Rhodes grass hay
	RG13	RG26	RG39	
Rhodes grass hay	130	260	390	
Soy hulls	225	170	120	
Ground maize	380	300	210	
Molasses	60	60	60	
Soybean meal	180	185	195	
Mineral mixture[2]	10	10	10	
Salt	5	5	5	
Lime	10	10	10	
Nutrient composition				
Dry matter g/kg	877	874	871	864
Crude protein g/kg	162	161	162	93
Metabolizable energy, MJ/kg	10.87	10.46	10.04	7.9
Neutral detergent fibre g.kg	280	331	383	697
Acid detergent fibre g/kg	178	204	232	408
Ash g/kg	74	83	92	97

[1]RG13: Total mixed ration (TMR) containing 13% RG hay on DM basis, RG2: TMR containing 26% RG hay on DM basis, and RG39: TMR containing 39% RG hay on DM basis

[2] di-calcium phosphate: 70.81%, salt: 18.91%, magnesium sulphate: 8.64%, ferrous sulphate: 8.64%, manganese sulphate 0.49%, zinc sulphate 0.22%, copper sulphate 0.03%, potassium iodide 0.009%, cobalt chloride 0.009% and sodium selenite: 0.0015%

Table 2 Composition of silage-based total mixed ration (dry matter basis) fed to crossbred calves from week 5 through week 8 post-weaning

Ingredients (g/kg of dry matter)	Silage-based total mixed ration	Maize silage
Maize silage	400	
Rhodes grass hay	200	
Ground maize	110	
Soy hulls	65	
Molasses	50	
Soybean meal	140	
Urea	10	
Mineral mixture[1]	10	
Salt	5	
Lime	10	
Nutrient composition		
Dry matter g/kg	500	305
Crude protein g/kg	161	75
Metabolizable energy, MJ/kg	9.6	9.6
Neutral detergent fibre g/kg	434	578
Acid detergent fibre g/kg	311	469
Ash g/kg	86	53
Calcium g/kg	9	3
Phosphorus g/kg	5	3

[1] di-calcium phosphate: 70.81%, salt: 18.91%, magnesium sulphate: 8.64%, ferrous sulphate: 8.64%, manganese sulphate: 0.49%, zinc sulphate: 0.22%, copper sulphate: 0.03%, potassium iodide: 0.009%, cobalt chloride: 0.009% and sodium selenite: 0.0015%

Calves were weighed at the start of the trial and then on a weekly basis. Faecal scoring was performed daily using a 1–4 point system in which score 1 was loose and 4 was hard faeces (Ireland-Perry *et al*., 1993). Body condition scoring was performed at the start of the experiment, then weekly, using a 1–5 scale scoring system with 0.25 increments in measurement (Wildman *et al.*, 1982). Withers height (WH), hip height (HH), heart girth (HG), and body length (BL) were measured at the start and after that weekly (Nemati *et al.*, 2015).

Feed samples were dried at 105 °C for four hours in a forced draft oven (Memmert UF450TS, Germany) to determine DM. Dried samples were ground to pass through a 1-mm screen using a Wiley mill (model no. 2, Arthur H. Thomas Company, Philadelphia, USA). The CP content (N × 6.25) was determined with Kjeldahl apparatus (Gerhardt Kjeldatherm, Germany), and ash contents by combustion at 550 °C for 5 hours (AOAC, 1991). The concentration of NDF and ADF (Van Soest *et al.*, 1991) were determined sequentially using an Ankom fibre analyser (Ankom2000, Ankom Technologies, USA). Sodium sulphite and heat-stable alpha-amylase (Ankom, Ankom Technologies, USA) were added during the NDF extraction process (Van Soest *et al.*, 1991).

Data were analysed using the PROC MIXED model function of SAS 9.3 (SAS Institute Inc., Cary NC). Weekly measures, including ADG, daily DMI, and faecal score, were analysed using repeated-measures ANOVA. The model included treatment, week, treatment × week and calf as a random factor. Data for structural measurement, BCS, gain and FE were analysed using one-way ANOVA. To determine the effect of the increasing hay level in the TMR, diet orthogonal polynomial contrasts were used. Initial bodyweights and structural measurements were taken as covariates for the parameters. The results were declared significant at P <0.05, and probability values between 0.05 and ≤ 0.10 were regarded as a trend towards significance.

Results

The results of DMI, ADG, FE, and BCS are presented in Table 3. Overall, from week 1 through week 8, DMI was similar between treatments (P >0.05). In phase 1, DMI tended to decrease linearly (P =0.07) with increasing hay concentration in the dry TMR, RG13 calves consumed 13% and 16% more DM than RG26 and RG39, respectively, whereas DMI was not different between treatments in phase 2.

Table 3 Effect of varying levels of Rhodes grass hay on the transition from a hay-based total mixed ration to a silage-based diet on intake, growth performance, feed efficiency and body condition score of crossbred calves

Traits[2]	Treatments[1]				*P*-value	
	RG13	RG26	RG39	SE	Linear	Trt × wk
Phase 1						
DMI, kg	2.88	2.50	2.42	0.155	0.070	0.293
ADG, kg	1.12	1.00	0.75	0.066	0.002	0.363
FE[2]	0.38	0.40	0.30	0.027	0.034	-
Phase-2						
DMI, kg	3.34	3.32	3.31	0.178	0.905	0.880
ADG, kg	0.84	1.08	1.05	0.035	0.001	0.004
FE	0.25	0.32	0.31	0.013	0.004	-
Overall						
DMI, kg	3.11	2.90	2.87	0.153	0.322	0.631
ADG, kg	0.98	1.03	0.90	0.041	0.247	0.020
FE	0.31	0.35	0.31	0.012	0.852	-
Initial BCS	2.87	2.58	2.70	0.108	0.208	-
Final BCS	3.25	3.12	3.17	0.100	0.760	-
BCS change	0.38	0.54	0.46	0.058	0.179	-

[1] RG13, RG26 and RG39; Total mixed rations containing 13%, 26%, and 39% of Rhodes grass hay (DM basis) that were fed during weeks1 through 4 post-weaning (Phase 1). During weeks 5 through 8 (Phase 2) all calves were fed a total mixed ration that contained 40% silage and 20% Rhodes grass hay (DM basis)
[2] ADG: average daily gain (kg/day), BCS: body condition score, DMI: dry matter intake (kg/day), FE: ADG/DMI

A treatment × week interaction for ADG was observed at weeks 1, 2, 3, 5, and 6 (Figure 1). Overall, a trend (P =0.089) was observed in ADG, with the RG26 group gaining 5% and 13% more weight than RG13 and RG39, respectively. In phase 1, ADG decreased linearly (P =0.001) with increasing concentrations of hay in the TMR with ADG being greatest for RG13 and least for RG39. In phase 2, ADG was greater for RG26 and the RG39, whereas it was lower for RG13 (P =0.001). A treatment × week interaction (P <0.05) was also observed at weeks 5 and 6 of phase 2.

During phase 1 and phase 2, FE was highest in RG26 (P <0.05). In phase 1, FE of RG39 was 23% and 18% lower than RG26 and RG13, respectively. Initial and final BCS and changes in them were not affected (P > 0.05) by the diet that was consumed in phase 1.

Similarly, initial, final and changes in structural measurements including WH, HH, HG, and BL, were similar (P >0.05) among treatments (Table 4). The results of faecal score are presented in Table 5. During phases 1 and 2, RG13 calves exhibited loose faeces compared with RG26 and RG39. A treatment × week interaction was also observed in weeks 5 and 6.

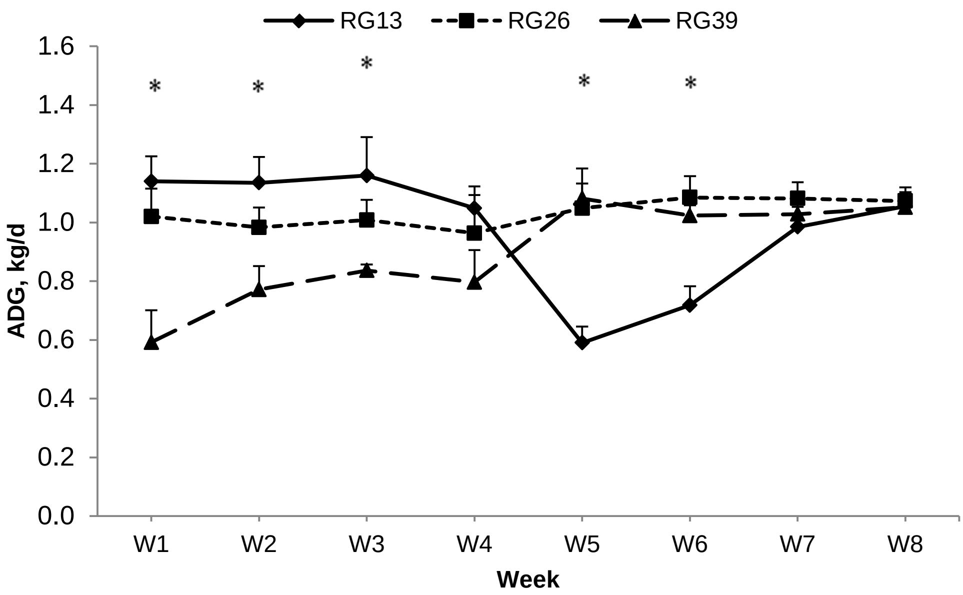

Figure 1 Weekly weight gain of crossbred calves fed Rhodes grass hay-based total mixed rations

RG13: Total mixed ration (TMR) containing 13% Rhodes grass (RG) hay (DM basis), RG26: TMR containing 26% RG hay (DM basis), RG39: TMR containing 39% RG hay (DM basis) RG that were fed in week 1 through week 4. A TMR that contained 40% silage and 20% RG hay (DM basis) was fed in week 5 through week 8. For each point, * shows significant difference at P <0.05

Table 4 Effect of varying hay levels in post-weaning total mixed rations on body measurements of crossbred calves

Variables	Treatments[1]			SE	*P*-value	
	RG13	RG26	RG39		Linear	Quadratic
Withers height, cm						
Initial	86.7	88.1	89.0	0.92	0.286	0.163
Final	97.0	99.1	99.1	1.05	0.399	0.914
Gain	10.1	10.3	11.0	0.98	0.398	0.910
Hip height, cm						
Initial	90.2	92.2	93.2	1.10	0.22	0.156
Final	98.9	101.9	102.4	1.31	0.375	0.995
Gain	8.8	9.2	9.8	0.72	0.372	0.996
Heart girth, cm						
Initial	93.3	94.1	96.5	1.17	0.68	0.077
Final	108.2	111.1	111.3	1.44	0.145	0.216
Gain	16.5	14.8	14.8	1.55	0.144	0.215
Body length, cm						
Initial	91.8	91.9	92.0	1.40	0.918	0.989
Final	107.1	108.3	109.9	1.74	0.056	0.885
Gain	17.9	16.4	15.3	0.84	0.057	0.886

[1] RG13, RG26 and RG39; Total mixed rations containing 13%, 26%, and 39% of Rhodes grass hay (DM basis) that were fed during weeks1 through 4 post-weaning (Phase 1). During weeks 5 through 8 (Phase 2) all calves were fed a total mixed ration that contained 40% silage and 20% Rhodes grass hay (DM basis)

Table 5 Effect of feeding varying hay levels in post-weaning total mixed rations on faecal score of crossbred calves

Items	Treatments[1]			SEM	*P*-value		
	RG13	RG26	RG39		Linear	Week	Trt × wk
Faecal score							
Phase 1	3.21	3.37	3.39	0.05	0.03	<0.001	0.198
Phase 2	3.80	3.82	3.87	0.03	0.16	0.285	0.004
Overall	3.50	3.59	3.63	0.04	0.04	-	-

[1] RG13, RG26 and RG39; Total mixed rations containing 13%, 26%, and 39% of Rhodes grass hay (DM basis) that were fed during weeks1 through 4 post-weaning (Phase 1). During weeks 5 through 8 (Phase 2) all calves were fed a total mixed ration that contained 40% silage and 20% Rhodes grass hay (DM basis)

Discussion

During phase 1, DMI decreased with increasing concentration of RG hay. Higher dry roughage levels increased the long particle distribution in the diets, thus reducing DMI (Greter *et al.*, 2008; Groen *et al.*, 2015). Decreased DMI can be associated with the higher NDF contents of the RG26 and RG39 compared with the RG13 diet (Hill *et al.*, 2010). The results for similar DMI in phase 2 are in line with those reported by Groen *et al.* (2015), which suggests that increasing the RG hay concentration had no carryover effect on DMI when calves transitioned to a silage-based TMR.

In weeks 1 through 4, ADG was lowest for RG39. Lower ADG in the RG39 calves may be associated with lower DMI during phase 1. Other possible explanations might be decreased DM digestibility (Hill *et al.*, 2010; Groen *et al.*, 2015) because of the higher concentration of dry roughage in the diet (Yang *et al.*, 2001) or the decrease in energy contents of the diet (11.00, 10.54, and 10.04 MJ/kg of ration) with increasing amounts of hay in TMR (Van Ackeren *et al.*, 2009). A treatment and week interaction was observed for higher ADG during weeks 5 and 6 of the experiment in RG26 and RG39. This may be related to better adaptability of rumen microbiota of the RG23 and RG26 treatment calves, which had previously been exposed to high forage diets in phase 1. Decreased weight gain in RG13 at weeks 5 and 6 following the dietary transition to a high-fibre diet could be related to the higher level of concentrate in the diet in phase 1, as high concentrate diets are known to decrease ruminal pH and reduce the population of rumen cellulolytic bacteria (Russell & Wilson, 1996). Another possible mechanism for the higher growth in RG 26 and RG 39 in phase 2 may be associated with well-established cellulolytic microbiota in RG26 and RG39, because previous exposure to high fibre, and consequently better fibre utilization, improved weight gain.

Animals reared on a high-fibre diet exhibit lower FE, which might be associated with poor digestibility of fibre (Hill *et al.*, 2010; Groen *et al.*, 2015). Improvements in FE occurred when high forage diets were replaced with high concentrate diets (Zanton & Heinrichs, 2007). Contrary to the current results, Hill *et al.* (2010) reported no difference in feed to gain ratio when varying levels of chopped grass hay were included in a weaned calf diet. A similar FE that was reported in a study by Hill *et al*. (2010) might be associated with lower inclusion (0%, 3%, 6%, and 9%) levels of hay. However, in the current experiment, the inclusion of RG was 13%, 26%, and 39%, which is much higher than those reported by Hill *et al.* (2010). In phase 2, RG26 and RG39 showed 15% and 14% higher FE than RG13. Poor performance in RG13 might be associated with higher intake of concentrate, consequently higher short-chain fatty acid production, lower ruminal pH (Laarman, *et al.*, 2012) and ruminal contraction (Owens *et al.*, 1998). Another possible mechanism is the reduction in absorption of volatile fatty acids (Leonhard-Marek *et al.*, 2007) because of keratinization of rumen papillae (Steele *et al.,* 2011). The better performances of RG26 and RG39 may be associated with better rumen development owing to higher NDF contents in the diet compared with RG13, Similar results were reported by Terré *et al.* (2013).

In the current experiment, no differences in body dimensions were observed between treatments, despite changes in ADG that can be attributed to the treatments. Likewise, no significant effects on BCS were observed. The current results for structural measurements were similar to previous findings in calves (Enevoldsen *et al.*, 1997; Hill *et al.*, 2010).

The loose faecal consistency that was observed in RG13 in phase 1 was associated with lower effective fibre intake because of less fibre in the diet. Higher grain intake in RG13 calves might have increased the post-ruminal flow of starch contents, leading to abnormal fermentation in the large intestine and loose faeces. Kleen *et al.* (2003) reported increased rumen osmolality, followed by a lower intake of effective fibre and higher starch intake, resulting in diarrhoea from the increased movement of water into the rumen.

Conclusion

A medium level of hay (26% RG on DM basis) in the diet is better for a smooth weaning transition and dietary adaptability of Friesian × Jersey calves from hay to a silage-based TMR during the post-weaning period. Growth performance and FE were improved in calves fed a diet that contained 26% RG on a DM basis.

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Authors' Contributions

ZAQ did data collection and write up, MAR participated in the planning and writing up the experiment, TNP was involved in formatting and revision. MIM carried out the critical revision, AS was in charge of formatting and revision. MR did laboratory analysis. HUR wrote up the document. MSY did critical revisions.

Conflict of Interest Declaration

The authors declare there is no conflict of interest.

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