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Research Article

Feed Delivery Frequency: A Bewildering Dairy Management Strategy

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Abstract

Due to numerous animal, feed and farm related factors affecting cow performance, feed delivery frequency remains an esoteric strategy in modern dairy management. The objective of this study was to determine Feed Delivery Frequency (FF) effects on feed intake and production performance of dairy cows offered chopped alfalfa hay based Total Mixed Rations (TMR) in a non-competitive environment. Eight multiparous, early-lactation Holstein cows housed in individual box stalls (4 × 3 m) received either once daily (1×) at 0700 h or 4 times daily (4×) at 0100, 0700, 1300 and 1900 h a chopped alfalfa hay (36.7% of dietary dry matter) based TMR. Two treatments were compared in a crossover design with two 20-day periods. Once instead of four times feed delivery increased dry matter intake (21.1 *vs.* 20.0 kg/d). Milk yield (31.1 kg/d), milk output of Net Energy for Lactation (NEL) (21.5 M cal/d), fat content (3.55%), protein content (3.20%) and milk NEL to intake NEL ratio (0.61) were similar between treatments. Therefore, under noncompetitive individual feeding and housing, greater feed delivery frequency of a mixed ration based on chopped alfalfa hay had no productive advantages. Increased energy and effective fiber intake by 1× instead of 4× feed delivery has benefits for high-producing cows facing metabolic pressures of early lactation.

Keywords: Feed delivery frequency; Early-lactation; Dairy cow; Milk

Introduction

Feed Delivery Frequency (FF) effects on dairy cow production and metabolism depend on farm (e.g., housing type, milking facilities), animal and diet related factors. Thus, because of interactions among these factors, theoretical predictions may not occur in practice. Greater feed delivery frequency of highly fermentable mixed rations and rapidly fermentable concentrates is thought to help stabilize rumen pH, and improve feed intake and milk production [1,2]. This may be related to reduced fermentation rate within a firmer rumen fiber mat that is hypothetically formed more effectively in more *vs.* less frequently fed ruminants.

Based on a review of the dairy literature, greater feed delivery frequency improved milk fat content and milk yield by 7% and 3%, respectively [3]. Improvements in microbial fibrolysis and milk fat can occur if greater feed delivery frequency can reduce rumen fermentation diurnal variations and hours of low rumen pH (<5.8) [1,4].

However, milk properties were unaffected by feeding a basal ration twice daily before delivering a protein supplement 2× or 5× daily [5], although rumen pH and propionate increased with the 5× treatment. Rumen fermentation patterns and cow performance have not been improved by greater feed delivery frequency (4× or 6× *vs.* 2×) in non-competitive environments [6-8]. Feeding a concentrate 2× *versus* 12× daily did not affect early-lactation cows performance on fat-depressing diets in tie stalls in one study [9], but increased milk fat content in another study (from 2.2% to 2.6%) [10]. Feed intake was increased by 4× instead of 2× feed delivery of a corn grain-based TMR in individual tie stalls [11]. Feeding 4× for 1× daily did not affect intake and production of mid-lactation cows in tie stalls offered a corn grain-based TMR with alfalfa hay and corn silage [12].

Once daily feed delivery is labor-effective and most desirable for many small- and mid-size farms. Because of labor and time costs, more frequent than 4× feed delivery is not feasible for even large dairy farms. A paucity of data exists for FF effects in untied individually-fed early-lactation cows. Also, feeding a combination of barley and corn grains instead of feeding them alone can optimize rumen health [13]. Feeding chopped alfalfa hay as the sole dietary forage source instead of a combination of alfalfa hay and coarse corn silage decreased rumen pH and increased Physically Effective NDF (peNDF) requirements [14]. Thus, dietary forage source and characteristics can affect cow response to FF. Farmers expect compelling economical justifications to overcome management challenges of more frequent feed deliveries. The objective of this study was to establish effects of 1× *versus* 4× daily feeding of chopped-alfalfa hay, corn-barley grain based TMR on feed intake and milk production of early-lactation cows in individual untied box stalls.

Materials and Methods

Cows, diets, and management

This experiment was conducted during July and August of 2010. Eight multiparous Holstein dairy cows (78.6 ± 17 days in milk; 577.5 ± 25 kg Body Weight (BW); 2.5 ± 0.2 Body Condition Score, BCS; and 33.0 ± 2 kg milk yield) were randomly assigned to once daily (1×) or 4 times daily (4×) feed delivery in a crossover design study (2 × 2) with two 20-day periods, two treatments, and 4 cows

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Table 1: Feed ingredients of the experimental total mixed ration.

Ingredient	% of diet DM
Alfalfa hay	36.7
Ground barley grain	18.3
Ground corn grain	14.7
Soybean meal (44% CP)	10.1
Whole cottonseeds	7.1
Cottonseed meal (solvent)	4.0
Fish Meal, Menhaden	3.1
Fatty acids-calcium soaps (powder)[1]	2.8
Minerals and vitamins supplement[2]	0.9
Calcium carbonate	0.8
Sodium bicarbonate	0.7
Di-calcium phosphate	0.5
Sodium chloride	0.3

[1]Berg+Schmidt (GmbH & Co.) KG, An der Alster 81, 20099 Hamburg, Germany.
[2]Contained 500000 IU vitamin A, 100000 IU/kg vitamin D, 100 mg/kg,vitamin E, 2000 mg/kg manganese, 196 g/kg calcium, 3000 mg/kg zinc, 96 g/kg phosphorus, 19 g/kg magnesium, 46 g/kg sodium, 3000 mg/kg iron, 3 g/kg sulfur, 300 mg/kg copper, 100 mg/kg cobalt, 100 mg/kg iodine, and 1 mg/kg selenium, 400 mg antioxidants per kg of supplement.

per treatment per period. Each period had 14 days of adaptation. A Total Mixed Ration (TMR, Table 1) was delivered either 1× at 0700 h or 4× at 0100, 0700, 1300 and 1900 h. Alfalfa is the most popular dietary forage in Iran [15,16]. The alfalfa hay, corn-barley grain based TMR was offered individually to allow for 5% to 10% orts on a daily basis. To help minimize sorting and selection of feed particles, pre-calculated water in exactly similar amount was sprayed onto the mixed concentrate and hay for individual cows to reduce diet DM to 80%. Forage and concentrate for individual cows were weighed daily and mixed thoroughly first in large bags and next manually in cement feed bunks. For the 4× group, daily hay and concentrate were divided into four exact similar portions before mixing with water for fresh TMR preparation at each feed delivery. Cows were housed indoor in individual 3 × 4 m box stalls with unlimited access to fresh water. Cows were allowed 1 h of daily exercise before the noon milking.

Feed and TMR analyses and nutrient digestibility

Corn and barley grains contained respectively 70% and 58% starch; 8.9% and 11.0% CP; 10.0% and 22.0% NDF; and, 4.3% and 2.2% ether extract (DM based). Grains were ground to pass through a 2-mm screen using a commercial hammer mill (model 5543 GEN, Isfahan Dasht, Isfahan, Iran). Alfalfa hay contained 93.0% DM, 13.8% CP and 45.0% NDF on a DM basis. Before mixing with the concentrate, alfalfa hay was chopped with a chopper machine (Agricultural Machinery Co., Tabriz, Iran) for an average theoretical chop length of 4 cm.

Feed intake for individual cows was measured daily for the entire experiment. Orts were collected just before the morning feed delivery and were analyzed for DM. Samples of TMR were taken daily at 0700 h during the 6 days of data collection. To determine DM, the TMR samples were oven-dried at 100°C for 24 h, and were ground to pass through 1-mm screen using a Wiley mill (Arthur H. Thomas Co., Philadelphia). Samples were analyzed for DM, ash, and N [17], and for ADF and NDF [18]. Organic matter was determined by ashing feed and fecal samples for 8 h at 550°C (method 942.05; [17]).

Milk sampling and analysis

Cows were milked 3× daily at 0630, 1230 and 2030 h in a milking parlor. Milk quantities were recorded during sampling days using graduated standardized milk jars (Alfa Laval Corporate AB, Rudeboksvagen, SE-226 55 Lund, Sweden) installed for individual cows. Milk samples for individual cows were collected during 2 days in each period from 6 consecutive makings into plastic vials containing potassium dichromate. Samples were taken from the 3 daily makings and composited proportionally according to the milk yield of each milking. The composited milk samples were analyzed for protein and fat using Milk-O-Scan (134 BN Foss Electric, Hillerod, Denmark). Daily data were pooled to obtain one value for each milk parameter per cow per period.

Statistical analysis

Data were analyzed using the mixed model procedure of SAS program. The method of estimating least square means was Real Maximum Likelihood, and the method of calculating denominator degrees of freedom was Kenward-Roger [19]. The effect of FF was tested in the following mixed model: Y = μ + FF + PD + Cow (PD) + e, where, Y = response variable, μ = mean, FF = Feed Delivery Frequency Effect, PD = Period Effect, Cow (PD) = Cow within Period Effect, and e = residual errors. Normality of distribution and homogeneity of variance for residuals were tested and ensured using Kolmogorov–Smirnov, Shapiro-Wilk, and Anderson–Darling tests [19] under Proc Univariate of the SAS program. The P-values ≤ 0.05 were declared as significant and those ≤ 0.10 were considered as tendency for significance.

Results and Discussion

Feeding 1× instead of 4× increased DMI by 1.1 kg (*P*=0.05; Table 2). Milk yields of fat (*P*=0.99) and protein (*P*=0.18), milk energy output (*P*=0.72) and orts as a percentage of TMR delivered (*P*=0.25) were similar between treatments (Table 2). The actual (*P*=0.16) and 3.5% fat-corrected milk (*P*=0.81) yields and feed efficiency (*P*=0.18) were similar for 1× *vs.* 4× FF. The present study provides novel insights into productive responses to FF (1× *versus* 4×) specifically in a non-competitive environment. Specially, the increased DMI and similar productivity by 1× instead of 4× feeding of a high-concentrate TMR challenge the concept that greater feed delivery frequency may improve feed intake and production of lactating cows.

Increased DMI by lower feed delivery frequency has been recently found in free-stall housed cows on grass silage, barley based rations (1× *versus* 5×, [20]; 1× *versus* 4× [21]). The greater DMI by lower feed delivery frequency was likely attributed to more relaxed environment due to reduced feeding related disturbances and increased laying time. Due to no significant differences in orts quantity between treatments, similar increases in NE_L and peNDF intakes were expected. Such an increased nutrient intake most likely contributed to the maintained milk production. The advantages of such concurrent increases in fermentable energy and peNDF intakes have recently been revealed [14].

The similar milk production between treatments agrees with Mantysaari *et al.* [20] who found no increases in milk yield despite

Table 2: Feeding frequency effects on nutrient intake, and milk yield, milk composition, and milk components yields.

	Feeding frequency			
Parameter	1×	4×	SEM	*P*-value
DMI, kg/d	21.1	20.0	0.48	0.05
Orts, % TMR delivered	7.6	10.0	1.89	0.25
NDF intake, kg/d	5.8	5.5	0.13	0.05
NE_L intake, M cal/d	36.4	34.4	0.83	0.05
Milk yield, kg/d	31.5	30.7	0.51	0.16
3.5% Fat-corrected milk, kg/d[1]	31.4	31.0	1.45	0.81
Milk yield / DMI	1.5	1.5	0.03	0.18
3.5% FCM / DMI	1.5	1.6	0.08	0.41
Milk NE_L density[2], M cal/kg	0.7	0.7	0.03	0.63
Milk NE_L output[3], M cal/d	21.7	21.4	0.81	0.72
Milk NE_L / NE_L intake	0.6	0.6	0.03	0.35
Milk fat, %	3.5	3.6	0.27	0.66
Fat yield, kg/d	1.1	1.1	0.08	0.99
Milk protein, %	3.2	3.2	0.04	0.81
Protein yield, kg/d	1.0	0.97	0.02	0.18
Milk fat / milk protein	1.1	1.2	0.11	0.58

[1]3.5% Fat corrected milk (FCM, kg/d) = (0.4324 × milk yield) + (16.21 × milk fat yield) [25].
[2]Calculated based on milk fat and protein content using the formula: NE_L (M cal/kg) = [(0.0929 × fat %) + (0.0547 × CP %)] [2].
[3]Milk NE_L density multiplied by daily actual milk yield.

increased DMI by feeding a grass silage, barley grain based TMR 1× instead of 5× daily. Milk fat yield was increased by 4× (0600, 1000, 1400 and 1900 h) instead of 1× (0600 h) feeding in grass silage-based TMR fed cows in free stalls, when the two groups were housed separately [21]. The increased milk fat yield was associated with reduced eating rate and total number of daily bites, greater self-grooming frequency, and a tendency for increased DMI. However, meal length, feed bunk presence and blood metabolites were not monitored by Phillips and Rind [21]. The current experiment is different from the study of Phillips and Rind [21] in housing (box stalls *versus* free stalls), dietary forage to concentrate ratio (37:63 *versus* 49:51), forage source (low-protein alfalfa hay *versus* grass silage), grain source ('barley + corn' *versus* barley), and feeding hours and intervals for the 4× treatment (0100, 0700, 1300, and 1900 h *versus* 0600, 1000, 1400 and 1900 h), respectively. Such differences may have contributed to different milk fat responses despite the increased DMI by 1× feed delivery in both studies.

Considering the similar milk energy outputs and a tendency for greater post-feeding concentrations of serum insulin in the 1× cows, the increased DMI may have contributed to reduced blood NEFA levels. Highly insulinergic diets might depress milk production [22]. The similar milk properties for 1× *versus* 4× feed delivery in the current study suggest no such insulin effects under non-competitive conditions.

The current study demonstrates that greater FF may offer no benefits to individually-housed early-lactation cows on high concentrate diets. Basically, increased FF can improve rumen fermentation and peripheral indicators of cow metabolism only if lower FF overly increases diurnal fluctuations of eating behavior and rumen conditions [2,23,24]. The sufficiently high milk fat, protein, and energy yields in the 1× cows indicate that even with increased intake level and elongated first meal, rumen fermentation may have not been disturbed.

Conclusion

Offering box-stall-housed, early-lactation, individually-fed untied cows a high-concentrate TMR based on alfalfa hay and corn-barley grains once instead of four times daily increased DM and energy intakes. Increased feed intake and maintained productivity by 1× *vs.* 4× feed delivery suggest that lower feed delivery frequency benefited metabolism of early-lactation dairy cows. The data demonstrate no benefits of greater feed delivery frequency of a hay-based high-concentrate TMR to early-lactation cows in a non-competitive environment.

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