Particle Size Evaluation and its Association with Feed Intake, Milk Yield and Chewing Activity in mid-lactation Holstein Cows

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Abstract

The objective of this study was to determine the associations among fresh and residual fractions of a total mixed ration (TMR), milk production and ruminating proportion of mid-lactation Holstein cows. During March 2002, daily representative TMR samples were collected at 8:00 a.m. from freshly delivered feed on a Holstein dairy in Florida. A sample of the residual feed (weigh-back) was collected at 7:30 a.m., corresponding to the weigh-back of the previous day. Samples were processed daily within 15 minutes of collection. Feed intake (as-fed), maximum and minimum temperatures of the day and individual milk yield were recorded daily. Each day, four hours after the 8 a.m. feeding (12 noon), numbers of cows ruminating and eating were counted. Particle size was evaluated using the Penn State particle size evaluator with three sieves. Dry matter (DM) content of each fraction was evaluated by using a microwave technique. Regression models for different outcomes were conducted. Models were developed using fractions as-fed and as DM basis.

Differences in DM content between coarse and medium size were not statistically significant. For all models, predictors were the same for both as-fed basis and DM basis. For dry matter intake (DMI), the only significant predictor was the minimum daily temperature, with a negative association. No variable was associated with weigh-back coarse fraction. However, when coarse and medium fractions were pooled as one fraction, maximum temperature of the day and DMI were predictors of this new outcome. For medium weigh-back fraction, significant predictors were fresh medium fraction proportion and DMI. Dry matter intake was negatively associated with medium fraction proportion. The proportion of cows ruminating was positively related to the proportion of cows eating four hours after fresh feed was placed on the feed bunk. Milk yield was negatively associated with the medium fresh fraction proportion of the day before.

Résumé

L'objectif de cette étude était de déterminer l'association qui existe entre les fractions fournies et rejetées de la ration totale mélangée (RTM), la production de lait et la proportion d'animaux en rumination chez des vaches Holstein en milieu de lactation. Des échantillons représentatifs de la RTM fraîchement distribuée ont été recueillis à 8 :00 AM quotidiennement en mars 2002 dans une ferme laitière de vaches Holstein en Floride. Un échantillon des rejets était recueilli à 7 :30 AM correspondant à la fraction non-consommée du jour précédent. Les échantillons étaient traités quotidiennement moins de 15 minutes suivant la cueillette. La prise alimentaire quotidienne du groupe a été déterminée en soustrayant le poids des rejets recueillis tôt le matin du poids de la ration fournie le jour précédent et en divisant par le nombre de vaches dans le groupe ce jour-là. La température minimum et maximum de même que la production individuelle de lait étaient notées quotidiennement. Le nombre de vaches qui ruminaient et qui s'alimentaient était compté à tous les jours quatre heures suivant le repas de 8 :00 AM. La taille des particules a été évaluée avec une tamiseuse à trois plateaux du *Penn State*. Le contenu en matière sèche de chacune des fractions a été évalué avec une technique micro-onde. Des modèles de régression avec sélection rétrograde des variables ont été utilisés pour chaque variable dépendante. Les modèles ont été développés pour les fractions sur la base de la quantité fournie ou de la quantité de matière sèche.

Il n'y avait pas de différence statistique dans le contenu en matière sèche pour les particules grosses ou moyennes. Pour tous les modèles, les variables prédictives étaient les mêmes peu importe si le calcul

se faisait sur la base de la quantité fournie ou de la quantité de matière sèche. Il y avait une relation négative entre la prise alimentaire de matière sèche et la température minimum journalière. Il n'y avait aucune association significative avec la fraction grossière des rejets. Toutefois, la température maximum journalière et la prise alimentaire de matière sèche prédisaient la fraction totale des rejets lorsqu'on combinait les fractions grossières et moyennes ensemble. La proportion de particules moyennes dans la ration fournie et la prise alimentaire de matière sèche prédisait la fraction moyenne des rejets. La prise alimentaire de matière sèche était associée négativement avec la proportion de particules moyennes dans la fraction. La proportion de vaches qui ruminaient était associée positivement avec la proportion de vaches qui s'alimentaient quatre heures après le repas. La production journalière de lait était associée négativement à la proportion de particules moyennes dans la ration fournie du jour précédent.

Introduction

Fiber is required to maintain normal rumen fermentation dynamics; consequently, it is an essential nutrient for ruminants and may be the most controversial and difficult to manage under practical feeding conditions.[16,17] Fiber is sometimes defined based upon chemical or physical characteristics. Acid detergent fiber (ADF) and neutral detergent fiber (NDF) are fiber fractions defined by their chemical composition. The National Research Council (NRC)[18] describes requirements for these fractions to balance diets at different stages of the production cycle of dairy cows. Physical fiber requirements, such as particle size, have only received peripheral discussion in this latter version of NRC, even though particle size has been demonstrated to affect dry matter intake (DMI), chewing activity, rumen pH and fermentation dynamics.[3,10] Effective NDF has been defined as the ability of feed to maintain milk fat percentage,[16] and physically effective NDF has been defined as the fraction of the diet that stimulated chewing activity and rumen mat formation.[17] These definitions are closely related to the concept of particle size.[1,2,16]

A methodology for evaluation of particle size, based on the American Society of Agricultural Engineers, has been developed (Penn State Particle Separator), which is a quick and cost-effective method of total mixed ration (TMR) particle size analysis.[9,11] The Penn State Particle Separator originally had three sieves. The two top sieves have rounded holes of 19 and 8 mm in diameter, respectively and a bottom screen to receive the finest fraction.[11] A new sieve with 1.18 mm rounded holes has recently been added to the device.[9] Design of the new device was based on the large variation among users of the original system (three sieves). In addition, under actual conditions, with TMR typically containing 40 to 60% concentrates, proportion of particles less than 1.18 mm becomes critical for the concept of physically effective NDF.[10,16]

In a previous study,[13] it was demonstrated that cows sorted feed depending on the initial content of coarse proportion in the TMR; however, the slope of the regression line was not large enough to be biologically important. A more important observation was that cows sorted feed independent of the initial forage particle size content of the TMR since the intercept was significantly higher in the regression line between initial and weigh-back coarse particle size proportion.

To contribute more practical information about the use of particle size analyzers, the following study was conducted. Objectives of the study were to determine the relationship between the fresh coarse portion and weigh-back coarse portion of the same TMR, considering the diet as-fed and on a dry matter (DM) basis. A second objective was to determine the relationship between fresh fractions of a TMR and the proportion of cows ruminating four hours after feeding, and milk yield in mid-lactation Holstein cows.

Materials and Methods

Dairy Farm

The study was conducted on a commercial dairy farm located in north-central Florida. The farm milked 3,000 Holstein cows three times a day with a mature equivalent (ME) 305 milk yield of 23,540 lb (10,700 kg), with a bulk-tank fat and protein content of 3.6 and 3.0%, respectively. Cows were housed in a free-stall system during the entire lactation, and provided with fans and sprinklers at the feed bunk area.

A TMR (Tables 1 and 2) was placed in the feed bunk three times a day, 10 to 15 minutes before milking was

Table 1. Composition of lactating cow diet.

Feed	% of diet, DM basis
Alafalfa hay	15.53
Cottonseed, whole	8.75
Corn silage	28.50
Corn hominy	19.93
Citrus pulp	6.25
Soybean meal 48	5.49
Wet Brewers grain	6.07
Lactating concentrate[a]	9.03
Lactating minerals	0.45

[a] Lactating concentrate composed by (dry matter basis): ground corn (38.3%), dry brewer grain (16.3%), wheat bran (15.4%), soybean meal (14.5%), fish meal (12.3%), vitamins and mineral (3.2%)

Table 2. Nutrient content of lactating cow diet.

Nutrient	Content
Dry matter content (%)[a]	46.90
Crude protein (CP), % dry matter (DM)[a]	18.60
Undegradable protein, % CP[b]	30.34
Degradable protein, % CP[b]	69.66
Soluble protein, % CP[b]	29.77
Net energy$_{Lactation}$ (Mcal/kg)[c]	1.76
Acid detergent fiber, % DM[a]	21.66
Neutral detergent fiber, % DM[a]	33.63
Non fiber carbohydrates, % DM[b]	41.13
Starch, % DM[b]	18.90
Lipid, % DM[a]	2.36
Ca, % DM[a]	1.10
P, % DM[a]	0.46
Mg, % DM[a]	0.36
K, % DM[a]	1.46
Na, % DM[a]	0.58
Cl, % DM[a]	0.48
S, % DM[a]	0.22
Forage in diet, % DM	44.03

[a] Laboratory nutritional analysis
[b] Values from feed composition tables
[c] From formulas after laboratory analysis

completed. The TMR was the same for cows between 25 days postpartum and dry-off (70 to 50 days before expected parturition).

Beginning 60 days postpartum, cows received bovine somatotrophin (bST)[a] every 14 days during the entire lactation.

Study Design

One side of a two-row free-stall barn with 160 cows in mid-lactation (100 to 160 days in milk) was used for the present study. The length and width of the barn were 321 feet (98 m) and 49 feet (15 m), respectively, with a double line of 87 free-stalls (174 total).

From March 1 to March 31 of 2002, daily representative fresh TMR samples were collected from the feed bunk immediately after 8:00 a.m., noon and 4:30 p.m. feeding. A sample of the residual feed (weigh-back) was collected at 7:30 a.m., corresponding to the residual of the previous day. Each sample was obtained by 10 representative sub-samples collected every 32 feet (10 meters) along the feed bunk. Sub-sample consisted of grabbing with one hand a random portion of the TMR, without shaking the hand, and putting the entire sample in a plastic bag. A composite was produced by commingling the 10 sub-samples in the bag. Samples were processed daily within 15 minutes of sample collection.

Feed intake was obtained by subtracting the daily weigh-back collected early in the morning from the daily fresh TMR fed the day before, and dividing by the number of cows in the barn that day.

Maximum and minimum daily temperatures were obtained from a weather station located nine miles (~15 km) from the farm. Individual milk yield was recorded daily by using the Afifarm system.[b] Any cow with a deviation of 25% or more in daily milk production was examined for disease conditions. If the animal was sick it was moved to a hospital facility; therefore, at all times the experimental barn was composed of healthy cows.

Each day, four hours after the 8:00 a.m. feeding (12 noon), numbers of cows ruminating, eating and sleeping were counted. The proportion of eating and ruminating cows was calculated. In each case, cows sleeping were not considered in the denominator.

Sample Processing

Fresh and weigh-back samples were processed daily after collection. The particle size evaluator with three sieves[11] was used, since the new four-sieve separator was not available at that time.

Each composite sample was placed in a plastic box and mixed until a homogeneous sample was obtained. About 0.55 lb (250 g) of this homogeneous sample was weighed and placed on the upper sieve of the particle size separator. The separator was shaken five times during eight cycles (one cycle corresponding to each side of the particle separator), according to manufacturer's recommendation. In this way, three fractions were obtained according to particle size. The upper portion was mostly composed of large (coarse) particles. The middle sieve was composed of smaller pieces of fiber (medium particle size). The bottom screen was composed of the smallest particles (mostly concentrates). The ration fractions in each screen were then weighed separately and a proportion from each fraction was calculated. After weighing the sample, a sub-sample for DM content evaluation was obtained from each fraction and fractions were re-calculated based on DM content as well. Dry matter content was evaluated by using a microwave technique. Fifty grams of a representative sample was spread evenly on a large paper plate. A 250 mL glass, three-quarters full of water, was placed in the back corner of the microwave oven to protect the oven magnetron when sample moisture was low. Sample was dried at maximum power for two minutes and weighed. Subsequently, the sample was dried at one minute intervals until sample weight became constant. Proportion of this weight over the original 50 g was considered as percentage of DM. Dry matter content was used to estimate DMI.

Statistical Analysis

Weigh-back coarse proportion (%), weigh-back medium proportion (%), proportion of ruminating cows (%), DMI (lb/d, kg/d) and milk yield (lb/d, kg/d) were used as outcome variables for statistical analysis. Regression models were conducted using SAS 9.1.[19] When an outcome variable was explained by only one independent variable, a regression line was constructed and plotted. Models were conducted using calculations as-fed and as-DM basis.

Regression models were defined as:

$$y = \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7$$

Where:

y = outcomes: DMI, coarse and medium weigh-back, milk yield, ruminating cows

β_1 = parameter of X_1

X_1 = effect of minimum temperature of the day (°C)

β_2 = parameter of X_2

X_2 = effect of maximum temperature of the day (°C)

β_3 = parameter of X_3

X_3 = effect of fresh coarse %

β_4 = parameter of X_4

X_4 = effect of fresh medium %

β_5 = parameter of X_5

X_5 = effect of DMI (when not dependent variable)

β_6 = parameter of X_6

X_6 = effect of proportion of cows eating

β_7 = parameter of X_7

X_7 = effect of double interactions

Results

Descriptive data for fresh coarse proportion, fresh medium proportion, fresh small proportion, weigh-back coarse proportion, weigh-back medium proportion, weigh-back small proportion, ruminating cow proportion, eating cow proportion, sleeping cow proportion, DMI and milk yield are presented in Figure 1. Mean of minimum temperature of the day was 49.7 ± 10°F (9.86 ± 5.59°C). Mean of maximum temperature of the day was 78.1 ± 8°F (25.61 ± 4.46°C).

Dry matter content of coarse fresh fraction and coarse weigh-back fraction was 44.9 ± 6.6 and 42.5 ± 6.1%, respectively ($P > 0.05$). Dry matter content of medium fresh fraction and medium weigh-back fraction was 46.1 ± 1.9 and 45.9 ± 7.0%, respectively ($P > 0.05$). Dry matter content of fine fresh fraction and fine weigh-back fraction was 49.6 ± 1.8 and 49.3 ± 7.3%, respectively ($P > 0.05$). However, coarse and medium fractions (both fresh and weigh-back) were statistically different from fine fresh and weigh-back fractions ($P \leq 0.05$). Differences between coarse and medium fractions were not statistically different ($P > 0.05$).

For all models, predictors were similar and had the same magnitude for both as-fed basis and DM basis. Therefore, summary of significant linear models based on fractions as DM basis will be discussed (Table 3). For DMI the only significant predictor was the minimum daily temperature, with a negative association (Figure 2). This indicated that when minimum temperature of the day increased the DMI decreased.

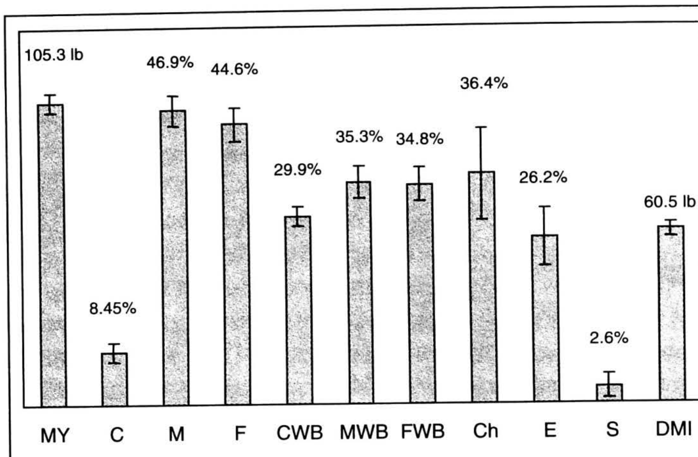

Figure 1. Descriptive data of fresh coarse, medium, fine proportion, weigh-back coarse, medium, fine proportion, chewing, eating, sleeping cow proportion, daily dry matter intake and milk yield in mature medium lactation Holstein cows.

MY: milk yield (lb/cow/d)
C: coarse %
M: medium %
F: fine %
CWB: coarse weigh-back %
MWP: medium weigh-back %
FWB: fine weigh-back %
Ch: chewing %
E: eating %
S: sleeping %
DMI: dry matter intake (lb/cow/d)

No explanatory variable was associated with weigh-back coarse fraction. However, when coarse and medium fractions were pooled into one new fraction, maximum temperature of the day and DMI were predictors of this new outcome. The higher the maximum temperature, the higher the proportion of coarse and medium fraction, indicating that animals consumed more concentrates than forages. The higher the DMI, the lower the coarse-plus-medium-fraction proportion.

For weigh-back medium fraction, significant predictors were fresh medium fraction proportion and DMI. The association between fresh medium and weigh-back medium fraction was positive, indicating that the higher the medium fraction in a fresh TMR the higher the medium fraction proportion in the weigh-back. Dry matter intake was negatively associated with medium fraction proportion. The higher the DMI, the lower the medium fraction proportion of the weigh-back.

For the proportion of cows ruminating four hours after feeding, the only predictor was the proportion of

Table 3. Summary of Linear Models with Particle Fractions expressed as dry matter basis.

Dependent		Independent	Coefficient	SEM	*P*-value	r^2
DMI[a] (kg/cow/d)	-	Minimum temperature (°C)	-0.06	0.03	0.04	0.18
Coarse plus Medium WB[b] %	-	Maximum temperature (°C)	0.54	0.29	0.08	0.39
	-	DMI (kg/cow/d)	-3.32	1.12	0.007	
Medium WB %	-	Medium fresh %	0.79	0.35	0.03	0.41
	-	DMI (kg/cow/d)	-3.13	0.77	0.0004	
Milk Yield (kg/cow/d)	-	Medium fresh %	-0.38	0.22	0.0008	0.23
Chewing %	-	Eating %	0.77	0.22	0.0001	0.23

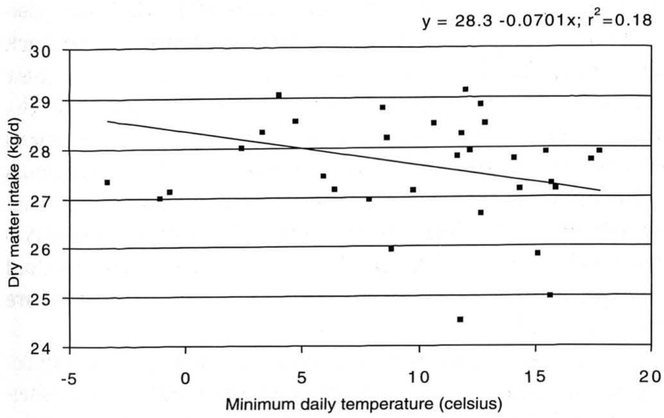

Figure 2. Regression line between minimum daily temperature (Celsius) and dry matter intake (kg).

cows eating four hours after feeding (Figure 3). The higher the proportion of cows eating, the higher the proportion of cows chewing their cud four hours after feeding.

Finally, for milk yield the only predictor was the fresh medium fraction proportion of the previous day (Figure 4). The higher the medium fraction proportion, the lower the milk production the next day.

Discussion

Diet

The diet of this dairy is typical of high producing farms in Florida. The NDF content of no less than 28% is within the standard recommended by NRC,[18] with 75% of NDF provided as forage.

The mean of the fresh coarse fraction was 8.45%, with a range between 6.05 to 11.9%. Under practical commercial conditions, this average and range is excellent for any particular farm. Corroborations for this consistent management of particle size was the level of milk production, low incidence of lameness within 30 days postpartum[14] (2.2%), and displacement of the abomasum within the first 60 days postpartum[15] (2%). In addition, the mean of the fresh coarse fraction was in accordance with the minimum levels recommended by the developers of the Penn State Particle Size Evaluator used in this trial, that is, no less than 6-8% for a TMR.[4,11] The low variation of the coarse fraction might be due to a consistent feed processing and ration preparation on the farm. Furthermore, sampling of the ration in the feed bunk and processing of the sample on the particle size separator was highly consistent, since a higher variation was found in a previous study conducted by the same authors[13] and a great effort was made to improve this aspect in the current study.

Cows eating and chewing their cud were 26.2 and 36.4%, respectively, after four hours post-feeding. In a previous study,[13] the proportion of ruminating cows was obtained at two hours after feeding and the proportion was 18.4%, which is 18% points less than the proportion of cows chewing their cud in the present study. A major reason for these differences may be that the current diet was higher in corn silage and alfalfa hay than the previous study diet. Corn silage induces greater chewing activity than other forages, such as alfalfa silage, or when it increases linearly in a TMR.[12,16] In addition, two hours after feeding may be too early to estimate the proportion of cows chewing their cud, consequently four hours after feeding might be a more appropriate time to measure this activity. However, when a TMR with a content of corn silage between 40 and 60% is fed, a proportion between 39 to 47% of the cows should be ruminating at any given time during the day. Also, animals eating a diet over 25% of forage NDF should spend between 650 to 750 minutes a day ruminating.[1,2] If this assumption is correct, about 40% of cows should be chewing their cud at any time. Therefore, the proportion of cows chewing their cud in the present study is in the lower limit of the normal range.[12]

Cows in this herd weighed near 1496 lb (680 kg), therefore the level of DMI (60.5 lb, 27.5 kg) was approximately 4.0% of BW, which is in accordance to NRC[18] for cows producing 105.6 lb/day (48 kg/day) of milk.

Models

Models provided essentially the same results when fractions were expressed as-fed or as-DM basis. Although in one study[10] moisture content of the TMR affected the analysis of the different fractions, results were similar

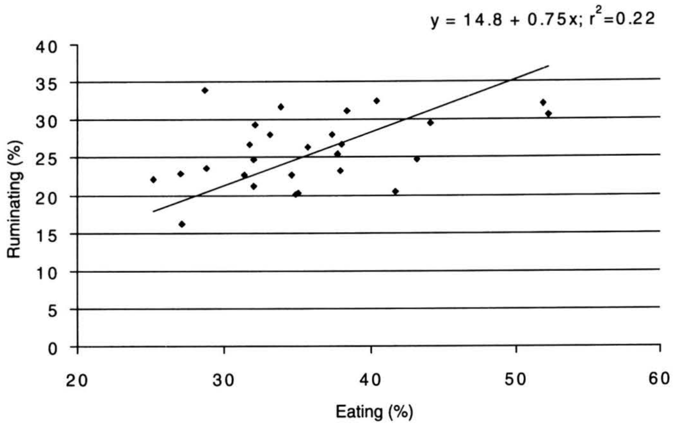

Figure 3. Regression line between ruminating cow proportion and eating cow proportion.

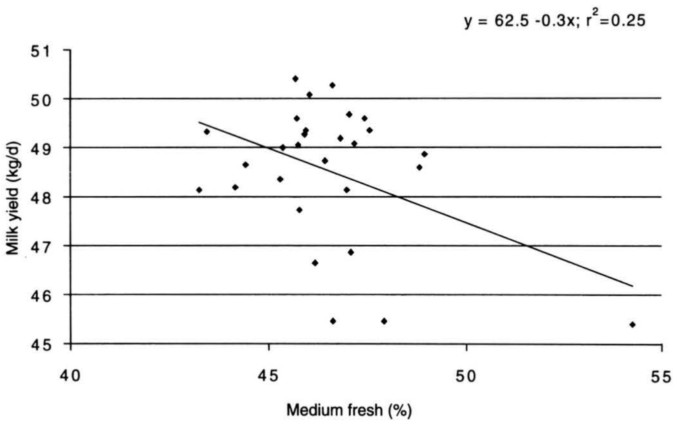

Figure 4. Regression line between daily milk yield (kg) and fresh medium fraction proportion.

between 35.6 and 57.4% of content of moisture. Since the DM content of the three fractions did not differ considerably (42 to 50%), it is reasonable to conclude that models in the present study provided essentially the same results when fractions were expressed as-fed or as-DM basis.

For DMI, the only explanatory variable was the minimum temperature of the day with a negative relationship. For each 1°C increase in minimum temperature, DMI decreased 70 g. In a study conducted by West *et al*,[20] mean ambient temperature was also related negatively to DMI. However, the effect was stronger (slope=0.85) and the relationship was between the daily temperature two days previous to the day of interest for DMI. In addition, the association was found in summer and not in spring, as in the present study. However, negative correlations between DMI and ambient temperature using the same-day measures have been reported in other studies, corroborating the present findings.[5] Although this model is a simple linear regression, 18% of the variation on DMI was explained by the minimum temperature of the day.

Weigh-back coarse fraction was not related to any variable included in the model. However, feed sorting was still evident since the weigh-back coarse fraction was significantly higher than the fresh coarse fraction (29.9 vs 8.45%; $P \leq 0.05$). This might imply that feed sorting is a natural behavior of cattle not related to the normal variation of physical characteristics of diet at the beginning of the feeding process, and/or there are other variables not identified by the present study that relate to the residual feed left by animals. When coarse and medium weigh-back were pooled in one fraction, maximum temperature of the day and DMI were significant predictors of this new variable. Maximum temperature of the day was positively associated with coarse plus medium weigh-back fraction, and DMI was negatively associated with the new variable. The first association may be explained by the higher caloric increment that forages produce in ruminants.[6] When maximum temperature is higher animals will consume less forages; therefore coarse and medium weigh-back fraction will be higher. The second association is logical since less DMI will determine more residual forage. At the same time, when ambient temperature increases, DMI decreases.[5,20]

Medium weigh-back proportion was positively related to medium fresh fraction and negatively associated with DMI. This means that for each one percent increment in medium fresh fraction, there is a 0.77% increment in the medium weigh-back fraction. This result is consistent with the findings reported by the group that developed the particle separator.[10] They reported that the higher the proportion of the fraction retained on the 8.0 mm sieve (short particle size corn silage), the higher the proportion of the fraction retained on the same sieve 24 hours after feeding. In regards to DMI, the proportion of weigh-back medium fraction decreased approximately 3% for each 2.2 lb (1 kg) increase in DMI. This association was not found in the opposite direction. In other words, DMI was not predicted by any particle fraction of the separator. In other studies DMI increased while particle size of the ration decreased.[8,10] Since the proportion of coarse plus medium weigh-back fraction was also predicted negatively by DMI, it is reasonable to assume that when DMI is maximized in a TMR, there is higher consumption of fiber fractions than when DMI is compromised.

Milk yield of the group was only predicted by the fresh medium fraction. The association was negative. Consequently, for each 1% increase in the fresh medium fraction the day before milk yield was measured, there was a decrease of 0.86 lb/cow/day (0.39 kg/cow/day) in milk production. This association is very complex and difficult to explain; as medium fraction proportion decreases, one of the other two fractions or both (coarse and fine) increases. In other studies, there were no differences in milk production based on different forage particle sizes of TMRs.[7,8] However in another study by the same group,[10] 3.5% fat-corrected milk production increased when particle size of corn silage of the TMR was of medium size. Unfortunately, this information cannot be extrapolated to the current study since the association between proportion of the different fractions and milk yield was not the major objective, and it was a secondary finding of the above mentioned studies.

Proportion of cows chewing their cud four hours after morning feeding was only predicted by the proportion of cows eating four hours after morning feeding as well. The association was positive, meaning that for each 1% increment in the proportion of cows eating there is a 0.75% increment in the proportion of cows chewing their cud four hours after the morning feeding. This association is difficult to explain. In a previous study[13] it was found that the proportion of cows ruminating two hours after fresh feed was placed in the feed bunk was slightly predicted by the fresh coarse proportion of the TMR. In the present study the same association was expected, but it was not found. This contradiction might be due to the wide range and variation of the fresh coarse fraction (3.2 to 32%) in the previous study, which was extremely high compared to the current fresh coarse fraction variation (6.8 to 11.8%). This is in agreement with other studies in which ruminating times were not affected by particle size of corn silage in TMRs with coarse fractions of low variability (2.9 to 15%);[10] but it is in disagreement with a similar study using alfalfa haylage as the source of fiber.[7] However, in that particular study, experimental diets had more variable coarse fractions and the group with the highest coarse fraction (31%) had the highest ruminating activity per unit of DM and NDF intake.

Conclusions

Coarse plus medium weigh back fractions were predicted by maximum daily temperature and DMI. Coarse fraction variability was not associated with any of the explanatory variables used in the studied models. Weighback medium fraction was predicted by fresh medium fraction and DMI. Milk yield was related to fresh medium fraction. The proportion of cows ruminating four hours after feeding was associated with the proportion of cows eating four hours after feeding. As a practical conclusion, when using the particle size evaluator, dry matter content of the TMR does not affect the interpretation of the results, and medium fraction proportion is inversely related to milk yield of the following day.

Acknowledgments

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Endnotes

[a] Posilac®, 500 mg sometribove zinc, subcutaneously; Monsanto, St. Louis, MO 63167.

[b] Afimilk®, S.A.E. Afikim, Kibbutz Afikim, 15148, Israel.

References

1. Allen MS: Relationship between fermentation acid production in the rumen and the requirement for physically effective fiber. *J Dairy Sci* 80:1447-1462, 1997.
2. Armentano L, Pereira M: Measuring the effectiveness of fiber by animal response trials. *J Dairy Sci* 80:1416-1425, 1997.
3. Bauchemin KA, Rode LM, Eliason MJ: Chewing activities and milk production of dairy cows fed alfalfa as hay, silage, or dried cubes of hay or silage. *J Dairy Sci* 80:324-333, 1997.
4. Heinrichs AJ, Buckmaster DR, Lamers BP: Processing, mixing and particle size reduction of forages for dairy cattle. *J Anim Sci* 77:180-186, 1999.
5. Holter JB, West JW, McGilliard ML: Predicting *ad libitum* dry matter intake and yield of holstein cows. *J Dairy Sci* 80:2188-2199, 1997.
6. Johnson DE, Ferrell CL, Jenkins TG: The history of energetic efficiency research: where have we been and where are we going? *J Anim Sci* 81(E. Suppl. 1): E:27-E38, 2003.
7. Kononoff PJ, Heinrichs AJ: The effect of reducing alfalfa haylage particle size on cows in early lactation. *J Dairy Sci* 86:1445-1457, 2003.
8. Kononoff PJ, Heinrichs AJ: The effect of corn silage particle size and cottonseed hulls on cows in early lactation. *J Dairy Sci* 86:2438-2451, 2003.
9. Kononoff PJ, Heinrichs AJ, Buckmaster DR: Modification of the Penn State forage and total mixed ration particle separator and the effects of moisture content on its measurements. *J Dairy Sci* 86:1858-1863, 2003.
10. Kononoff PJ, Heinrichs AJ, Lehman HA: The effect of corn silage particle size on eating behavior, chewing activities, and rumen fermentation in lactating dairy cows. *J Dairy Sci* 86:3343-3353, 2003.
11. Lammers BP, Buckmaster DR, Heinrichs AJ: A simple method for the analysis of particle sizes of forage and total mixed rations. *J Dairy Sci* 79:922-928, 1996.
12. Maekawa M, Bauchemin KA, Christensen DA: Effect of concentrate level and feeding management on chewing activities, saliva production, and ruminal pH of lactating dairy cows. *J Dairy Sci* 85:1165-1175, 2002.
13. Melendez P, Rodríguez O, Madrid S, Donovan A: The association between forage particle size at initial feeding and the weigh back and chewing activity in dairy cattle. *Bov Pract* 36:66-70, 2002.
14. Melendez P, Bartolome J, Archbald L, Donovan A: Association between lameness, ovarian cysts and fertility in lactating dairy cows. *Therio* 59:927-937, 2003.
15. Meléndez P, Donovan A, Risco CA, Hall MB, Littell R, Goff J: Effect of calcium-energy supplements on calving-related disorders, fertility and milk yield during the transition period in cows fed anionic diets. *Therio* 60:843-854, 2003.
16. Mertens DR: Creating a system for meeting the fiber requirements of dairy cows. *J Dairy Sci* 80:1463-1481, 1997.
17. Mertens DR: Physically effective NDF and its use in formulating dairy rations. *Proc 11th Annual Florida Ruminant Nutrition Symposium* 141-160, 2000.
18. National Research Council: Nutrient requirements of dairy cattle, 7th revised ed. Washington, DC: National Academy Press, 2001.
19. SAS, SAS/STAT Software: Change and enhancements through release 9.1 for windows. SAS Inst. Inc., Cary, NC, 2003.
20. West JW, Mullinix BG, Bernard JK: Effects of hot, humid weather on milk temperature, dry matter intake, and milk yield of lactating dairy cows. *J Dairy Sci* 86:232-242, 2003.