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The Association Between Forage Particle Size at Initial Feeding and the Weigh-Back and Chewing Activity in Dairy Cattle

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Abstract

A field trial was conducted at the University of Florida Dairy Research Unit to determine the relationship between initial coarse portion (ICP) particle size of a total mixed ration (TMR) and orts (weigh-back coarse portion, WBCP) of the same TMR. Additionally, the relationship between the ICP of a TMR and the proportion of cows chewing their cud 2.0 hours after feeding was determined. A random representative sample of TMR was taken from the feed bunk at initial feeding and 8 h later (weigh-back) every day from the same barn for 75 days. Samples were analyzed for particle size content using a particle size evaluator. Proportion of the largest particles of the TMR was recorded. Additionally, the proportion of cows ruminating 2.0 hours after the morning feeding was recorded each day. Correlation and regression models between ICP and WBCP, and between ICP and the proportion of ruminating cows were calculated. The mean and standard deviation for ICP, WBCP and proportion of cows cud chewing were 14.2% ± 6.6%, 29.9% ± 13.2% and 18.4% ± 5.0%, respectively. The Pearson correlation coefficient between ICP and WBCP was 0.53, and the correlation coefficient between the proportion of cows chewing their cud and ICP in the TMR was 0.19. Initial coarse proportion was a predictor for WBCP ($p < 0.01$), but was not a predictor of the proportion of cows ruminating 2 h after the morning feeding ($p > 0.05$). These findings are suggestive of sorting of the TMR by the cows. Sorting was significantly higher ($p<0.01$) as the coarse proportion at the initial feeding increased, but this difference was likely of little biological significance.

Résumé

Un essai sur le terrain a été mené à la University of Florida Dairy Research Unit pour établir la relation entre la taille des particules de la portion initiale brute (ICP) de la ration totale mélangée (TMR) et les restants (parties non-retenues de la portion initiale, WBCP) de la même ration. De même, la relation entre l'ICP d'une TMR et la proportion des vaches qui ruminaient encore plus de 2 heures après la prise de nourriture a aussi été examinée. Un échantillon aléatoire représentatif a été pris de la mangeoire au début du repas et 8 heures plus tard (partie non-retenue) à tous les jours dans la même ferme durant 75 jours. Les échantillons ont été analysés pour déterminer la composition en terme de taille des particules à l'aide d'un appareil d'estimation de la taille des particules. La proportion des particules les plus grossières dans la TMR était notée de même que la proportion des vaches qui ruminaient encore 2 heures après le début du repas du matin. La corrélation et le modèle de régression ont été utilisés pour établir la relation entre l'ICP et le WBCP et entre l'ICP et la proportion des vaches qui ruminaient encore après 2 heures. La moyenne et l'écart type de l'ICP, de la WBCP et de la proportion de vaches qui ruminaient encore après 2 heures étaient dans l'ordre de 14.2% ± 6.6%, 29.9% ± 13.2% et de 18.4% ± 5.0%. Le coefficient de corrélation de Pearson était de 0.53 entre l'ICP et le WBCP et de 0.19 entre la proportion de vaches ruminantes et l'ICP dans le TMR. La proportion initiale de particules grossières prédisait la valeur de la WBCP ($p < 0.01$) mais non celle de la proportion des vaches qui ruminaient encore 2 heures après le repas du matin ($p > 0.05$). Ces

résultats indiqueraient un tri de la TMR par les vaches. Ce tri était plus prononcé ($p < 0.01$) lorsque la partie grossière de la portion initiale était accrue. Cette différence n'était probablement pas importante au niveau biologique.

Introduction

Fiber is an essential nutrient for ruminants, and perhaps one of the most controversial and difficult nutrients to manage under practical feeding conditions. The recommended crude fiber, acid detergent fiber (ADF) and neutral detergent fiber (NDF) to balance diets at different stages of the production cycle of dairy cows has been described by the NRC.[11] Actually, fiber requirements have been described as effective NDF, related to chewing activity and to milk fat content.[6,8] However, NRC[12] has not considered an effective fiber requirement because of the lack of a standard validated method of measurement. Additionally, NDF has a different meaning if it originates from forage versus non-forage sources.[5,8]

Particle size of forages has been considered as a predictor of the performance and health disorders of dairy cows. This has been based on the effect of particle size on cud chewing activity, saliva production and ruminal fermentation patterns.[8,16] Some studies have recommended levels no less than of 6% of particle size greater than 19 mm in a total mixed ration (TMR) by using a particle size evaluator.[7] Most studies have focused on the minimum amount of fiber necessary to maintain normal ruminal physiology; however, no upper limits have been established. Under practical conditions it has been suggested that an excessive proportion of particle size greater than 19 mm (over 20% of the fresh diet) might induce a sorting process by the cow, which might be as detrimental as diets with very low large particle size or excessive concentrate content.[13]

The hypothesis of this study was that a higher proportion of large particle size in a fresh diet induces a sorting process by the animals, which is confirmed by a higher proportion of larger particle size in the feed residue (weigh-back).

The objective of this study was to determine the relationship between the initial coarse portion (ICP) of a TMR and weigh-back coarse portion (WBCP) of the same TMR, and to determine the relationship of ICP of a TMR to the proportion of cows ruminating 2.0 hours after feeding.

Materials and Methods

Dairy Farm

The study was conducted at the Dairy Research Unit, University of Florida, during January to March of 2000. The farm is located in north Florida, with 550 milking cows milked three times a day and fed after each milking. The rolling herd average milk production, percent milk fat and percent milk protein was 22,088 lb (10,040 kg), 3.6% and 3.0%, respectively. Cows were housed in a free-stall system during the entire lactation and were provided fans and sprinklers at the feed bunk area.

Cows and Feed Management

One side of a two-row free-stall barn (420 ft [137 meters] long, 50 ft [15 m] wide) with 200 free-stalls and an average of 225 cows daily was used for the study. Cows were within the first 150 days of lactation at the beginning of the trial and received the same TMR three times each day. Diet composition and nutritional content of the diet are shown in Tables 1 and 2, respectively.

Study Design

During a 75-day period, a random TMR sample was collected daily from the feed bunk immediately after being offered to cows at 7:00-7:30 AM (initial). A second sample was collected 8 hours later, just before the next feeding (weigh-back). Samples were obtained by collecting 10 representative samples every 32.8 ft (10 meters) along the 328 ft (100 m) feed bunk each day. A composite was produced by commingling the 10 samples in a plastic bag. Initial and weigh-back samples were processed daily within 15 minutes of sample collection. Sample collection and processing were conducted by the same person during the entire trial.

Sample Processing

The Penn State particle size evaluator consisting of three screens was used for sample fiber evaluation.[7] The upper screen has circular holes of 19 mm diameter, the middle screen contains 11 mm diameter circular holes and the bottom tray has no holes.

Each composite sample was placed in a plastic box and mixed until a homogeneous sample was obtained. Two-hundred and fifty (250) gm of this homogeneous

Table 1. Diet composition of the lactating herd.

Feed	Dry matter basis (%)
Corn silage	25.40
Alfalfa hay	11.23
Cottonseed hulls	4.62
Citrus pulp	8.70
Prolac[1]	1.41
Corn meal	23.1
Soybean meal	9.0
Whole cottonseed	12.72
Mineral/vitamin mix	3.82

[1]Prolac: Commercial supplement; 66.7% crude protein; 10.5% fat; 1.68 Mcal ENl/kg DM

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Table 2. Nutritional composition of the diet.

Nutrient	Level
Dry matter (%)*	59.54
Energy net of lactation (Mcal/kg DM)[1]	1.66
Crude protein (% DM)*	17.39
Undegr. protein (% DM)[1]	5.89
Degr. protein (% DM)[1]	11.50
Soluble protein (% DM)[1]	5.61
ADF (% DM)*	24.56
NDF (% DM)*	34.96
Effective NDF (% DM)[1]	22.30
NSC (% DM)[1,2]	38.16
Starch (% DM)[1]	19.95
Ca (% DM)*	0.91
P (% DM)*	0.40
K (% DM)*	1.40
Mg (% DM)*	0.32

[1]Values from nutritional tables and formulas
[2]Non-structural carbohydrates
*Laboratory determination

sample was weighed and placed on the upper screen of the particle size separator. The separator was shaken five times during 8 cycles (1 cycle corresponding to each side of the particle separator), according to manufacturer's recommendation. In this way, three fractions were obtained according to the particle size. The upper portion is mostly composed of effective fiber or forages (larger particle size or coarse). The middle screen is composed of smaller pieces of fiber (medium particle size). The bottom screen is composed mostly of concentrates and the smallest particles. The ration fractions in each screen were then weighed separately and the proportion from each fraction was calculated.

Cud Chewing Activity

Each day, two hours after the morning feeding, the total number of cows in the barn and the number of cows experiencing cud chewing activity were counted. The proportion of ruminating cows was calculated.

Statistical Analysis

The initial coarse portion, WBCP and the proportion of ruminating cows were used for statistical analysis (outcome variables). To determine if these proportions were normally distributed, the Wilk-Shapiro statistic was conducted. If the data were normally distributed they could be used in a general linear model. If not, a logarithmic transformation of the variable was performed to normalize the distribution.

A Pearson correlation statistic was calculated between ICP and WBCP, and between ICP and ruminating cow proportion, using the Cancorr Procedure of SAS 7.0.[14]

Using the GLM procedure of SAS 7.0,[14] a General Linear Model was set for WBCP and ruminating cows proportion as dependent variables. The objective of these two models was to determine if the ICP was a predictor of the WBCP and the proportion of cows chewing their cud after feeding (regression analysis).

Model 1:

$$Y_i = \mu + \alpha_j + e_k$$

Where

Y_i = weigh-back coarse proportion (WBCP)
α_j = fixed effect of initial coarse proportion (ICP)
e_k = error term

Model 2 :

$$Y_{ij} = \mu + \alpha_i + \beta_j + e_{ij}$$

Where

Y_{ij} = ruminating cow proportion
α_i = fixed effect of initial coarse proportion (ICP)
β_j = fixed effect of the square ICP (quadratic effect)
e_{ij} = error term

Results

The Wilk-Shapiro statistics for ICP, WBCP and ruminating cows proportion were 0.97, 0.98 and 0.97, respectively. This indicates that the three variables had a normal distribution pattern (Wilk-Shapiro > 0.95).

Descriptive data on the three variables ICP, WBCP and cud chewing cows proportion are presented in Table 3.

The Pearson correlation coefficient between ICP and WBCP was 0.53; the correlation between the ruminating cow proportion and the ICP was 0.19. The graphical relationship for these two models is shown in Figures 1 and 2.

The ICP was a significant predictor of WBCP (Table 4), but was not associated with the proportion of cows ruminating 2 hours after the morning feeding (Table 5).

Discussion

Diet

The diet at this dairy is typical of those fed on dairy farms in Florida. The NDF content of no less than 25-28% is within the standard recommended by NRC,[12] with 75% of NDF provided as forage. However, NDF alone is not adequate for ration balancing. Fiber varies in its effectiveness in stimulating chewing. The effectiveness

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Table 3. Descriptive statistics of variables.

Statistics	ICP[1] (%)	WBCP[2] (%)	Ruminating cows (%)
Mean	14.2	30.1	18.4
Median	12.8	28.8	18.6
Minimum	3.2	4.8	8.4
Maximum	32.0	58.4	32.6

[1]ICP: Initial coarse proportion of diet
[2]WBCP: weigh-back coarse proportion of diet

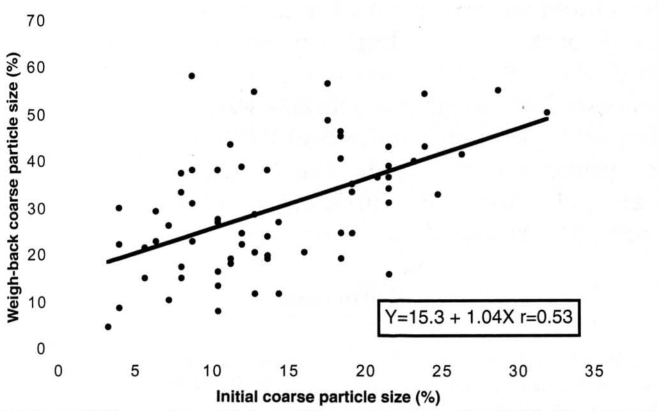

Figure 1. Scatter plot between initial coarse proportion (ICP) and weigh-back proportion (WBCP).

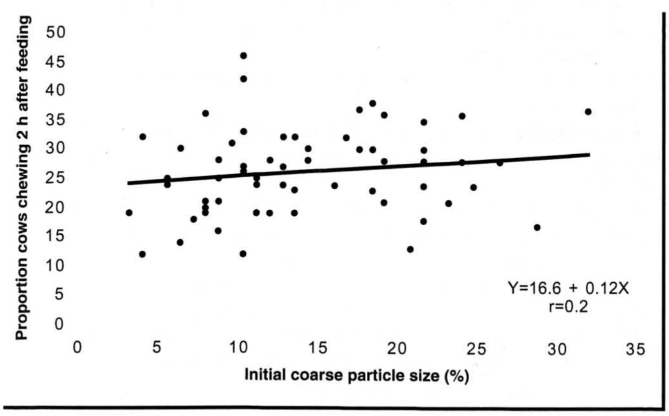

Figure 2. Scatter plot between initial coarse proportion (ICP) and chewing rate 2.0 hours after feeding.

of stimulation of chewing fiber varies as the particle size and retention times of indigestible and digestible fiber vary.[16] Additionally, Allen[1] recommended considering not only the physical effectiveness of fiber, but also the production of fermentation acids in the rumen. Other indicators of proper fiber nutrition are milk fat content, milk yield and the incidence of some health disorders.[10,12,15]

Particle size evaluation was not a routine function on this dairy farm. The mean ICP (14.2%) was above

Table 4. Analysis of parameter estimates for weigh-back coarse proportion.

Parameter	DF[1]	Estimate	Std error[2]	*p*-value
Intercept	1	15.3	5.8	0.0004
Initial coarse proportion	1	1.04	0.21	0.0001

[1]Degree of freedom
[2]Standard error

Table 5. Analysis of parameter estimates for ruminating cows proportion.

Parameter	DF[1]	Estimate	Std error[2]	*p*-value
Intercept	1	16.6	1.46	0.0001
Initial coarse proportion	1	0.12	0.09	0.10

[1]Degree of freedom
[2]Standard error

the minimum levels recommended by the developers of the particle separator used in this trial, that is, no less than 6-8% for a TMR.[7] However, the range in ICP of 3.2 to 32% was greater than anticipated. This wide range was observed in a ration in which there was no 'theoretical' change in composition or source of commodities. Four factors may have played a role in variation in particle size; feed sampling, feed processing, ration fabrication and particle separator intravariation coefficient.

Sampling of the ration in the feed bunk may have been imprecise. All attempts were made to take a sample that was representative of the ration at each of the 10 sites along the feed bunk. Taking multiple samples for the composite sample should have given a fair estimate of what was offered to the cows. Some variation in processing of samples could have occurred. A non-representative 250 gm sub-sample may have been used for processing, or the intensity of the "shake" of the particle size separator may have varied from sample to sample. We could not possibly measure this latter function, but every effort was made to be consistent for each sample and only one of the investigators did all sample processing.

Several variations in feed fabrication could contribute to the variation in ICP. Variation in mixing times and the precision with which farm personnel add prescribed commodities to each batch of feed could theoretically impact ICP measurements seen in this study.

Finally, particle separator intravariation coefficient is important to mention. We do not rule out the possibility that the same composite sample processed by the same investigator twice may give different re-

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sults. This is the previous experience of the authors (unpublished data).

Cows eating a diet with forage particle length over 12 mm and over 25% of total 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. In our study, 2.0 h after the morning feeding, only 18.4% of the cows were ruminating, with a range of 8.4 to 32.6%. Based on data presented above, rate of rumination in the study cows was low. The interval between feeding and measurement of chewing activity may not have been ideal (2.0 h); some cows may have still been eating or doing some other function that would not put them at risk of cud chewing.

Model 1

Model 1 is described by the equation:

WBCP = 15.3 + 1.04 (ICP) $(R^2=0.29)$

Where:

WBCP = weigh-back coarse proportion
ICP = initial coarse proportion

Although this model is a simple linear regression, 29% of the variation in the WBCP is explained by ICP. The intercept of 15.3% indicates that there is a sorting process even at low levels of ICP. The slope of 1.04 is indicative of a sorting process at higher levels of ICP (a slope of 1.00 would indicate no sorting of feed components). This latter finding may have been statistically significant, however, as seen in Figure 1, there is likely no biological significance of this finding. Sorting implies cows eat the most succulent part of the diet, that is, the concentrate and the highest quality forage. In this sense, extremely high particle size would be as unfavorable as a low proportion of coarse portion at the beginning of the feeding process. In both cases, chewing activity might be depressed, with less saliva production and low buffering of the rumen.[1,3,6] Low ruminal pH may decrease DMI, fiber digestibility and microbial yield, and thus decrease milk production and increase feed cost.[1]

Model 2

In model 2, ICP was not a good predictor of the proportion of cows chewing their cud 2.0 h after feeding. The correlation coefficient between these two traits was only 0.19 ($p > 0.05$; Figure 2) and the coefficient of the regression model tended to be significant ($p=0.10$; Table 5). Chewing behavior is highly variable in cattle. This is dependent on environmental factors such as feeding and milking schedules, patterns of lighting,[3] and type, quantity or physical form of forage.[1,6,8,16] However, the most consistent factors related positively with time spent cud chewing have been the NDF content of the diet, effective NDF content and particle size of the forage portion.[1,4,5,6,8,16] Cows ruminate about 10 to 12 hours a day. This process occurs concurrently with other activities such as nursing, walking, scratching, urinating and defecating, and occurs in both standing and lying positions. Rumination in dairy cattle occurs during 10 to 20 periods each day, ranging from 1 minute to more than 2 hours.[3]

Conclusions

Forage particle size at the beginning of feeding is correlated positively with the forage particle length at weigh-back (r=0.53). Both smaller and excessive particle size have to be considered when a TMR is being processed. Although particle size was not related to the proportion of cows ruminating 2.0 h after feeding, the low proportion of cows chewing their cud suggests cows were not consuming sufficient effective fiber, which might be a result of the sorting process.

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