

THE EFFECT OF FORAGE PARTICLE SIZE ON DAIRY CATTLE

P.J. Kononoff
Department of Dairy and Animal Science
The Pennsylvania State University
E-mail: pjk168@psu.edu

Introduction

Ruminants require forage fiber in a coarse physical form. Increasing fiber level and forage particle size has been shown to effectively increase chewing activity and is believed to increase saliva flow, rumen pH, acetate-to-propionate ratio and milk fat levels (Cassida and Stokes 1986; Mertens, 2000). Although impaired rumen fermentation and function can result in cattle fed rations lacking in physical structure, excessive amounts of long, coarse forage may also limit intake and digestibility, ultimately affecting energy balance of the animal (Allen 1997).

Current NRC guidelines have proven useful in defining animal requirements and feed composition but do not provide detailed recommendations on ration physical form. The concept of effective fiber was created to unite the chemical and physical nature of the forage, and to quantify its value to rumen function. Chewing and rumination are known accurate measurements of the roughage characteristics for ruminant diets (Sudweeks et al. 1981). Physically effective NDF (peNDF) is defined as that dietary fiber source which effectively stimulates rumination and salivation (Mertens 1997). Poppi et al. (1985) determined that particles that were retained on a sieve measuring 1.18-mm pass out of the rumen slower than those, which are not retained. Mertens (1996) suggests that in order for particles > 1.18-mm to pass out of the rumen they would have to be reduced through pulverization and as a result these particles would stimulate more saliva secretion than those < 1.18-mm.

The ability to routinely measure ration particle size has been difficult until the introduction of The Penn State Particle Separator (PSPS). Using the PSPS, a particle distribution is determined by separating particles according to size; those > 19.0-mm, those between 19.0 and 8.0-mm and those < 8.00-mm (Lammers et al. 1996). With the construction of an additional screen (1.18-mm), the PSPS is capable of making peNDF measurements proposed by Mertens (1996). Additionally the third screen may be useful in measuring the particle size of non-forage fiber sources as well as processed grains.

Effect of Forage Particle Size on Intake

The effect of particle size on feed intake is unclear with conflicting results being reported (Kennedy and Doyle 1993). Few authors have observed effects of alfalfa silage on intake when well-balanced rations are fed to mid-lactation cows (see Table 1). Positive effects with reduced particle size on DMI have been reported in some studies feeding corn silage of different particle size (Stockdale and Beavis, 1994) but have not been observed in

others (see Table 2). Difficulty in interpreting the response of particle size on DMI may be in part due to digestibility and specific gravity, factors independent of the individual feeds particle size (Dulphy and Van Os 1996). Furthermore, the degree of particle size reduction varies depending upon processing and particle size determination methods used, making treatment types difficult to quantify in relation to others.

When detected, intake response to reduce particle size is usually positive with the magnitude depending upon the extent of particle reduction, the type and digestibility of forage and the energy status of the animal. Positive effects with reduced particle size have been noted in many poor quality forages containing high cell wall contents (Kusmartono et al. 1996). Although several authors have reported increased DMI with reduced particle size while feeding high quality forages (Beauchemin 1997) most authors report that no effect on DMI occurs when good quality forage is fed alone or included in a ration meeting NRC requirements (see Tables 1 and 2). Literature appears to support the hypothesis that DMI is influenced by particle size reduction only when a poorly digestible feed with a high cell wall content are fed and no effects occur when good quality forages are fed.

Eating and Rumination Activities

Chewing and rumination are known accurate measurements of the roughage characteristics for ruminant diets (Balch 1971). Increasing total ration NDF level and ration particle size has been shown to increase rumination time, resulting in increased saliva flow which buffers rumen pH, all factors used to measure effectiveness of forage fiber source (Cassida and Stokes 1986).

Increasing alfalfa particle size has been shown to increase rumination time, resulting in increased saliva flow buffering the rumen environment. When feeding chopped and dehydrated alfalfa both Beauchemin (1997) and Shaver et al. (1988) did not observe differences between different chop lengths but differences in rumination times between chopped hay and finer dehydrated forage products were seen. Increased mean rumen pH levels accompanied increased rumination times.

Differences between eating, ruminating, and total chewing activity (TCA) are often not observed when feeding corn silage of different particle size. Both Bal et al., (2000) and Schwab and Shaver (2001) observed that fine cut length reduced eating activity but did not effect rumination or total chewing time per kilogram of DMI. As a result of these observations it seems likely that increasing corn silage particle size increases the sorting tendency of dairy cattle, ultimately resulting in the diets being consumed being different than those formulated.

Rumen pH and Digestion

Complete understanding of the dynamic nature of ruminal fermentation is difficult due to the multitude of factors affecting it. Although a number of studies have been designed in an attempt to further understand the effects of particle size on ruminal fermentation, little

uniformity exists (Tables 1 and 2). In a review of published studies examining the effects of different theoretical cut lengths (TLC) of alfalfa silage and corn silage, no significant differences were observed in dry matter digestibility. Dry matter digestibility does not appear to be linked to different cut lengths of silages however differences have been observed when forages are excessively ground or when dehydrated forms are fed (Beauchemin et al. 1997; Rodrigue and Allen, 1960).

Although increasing particle size often results in increased rumination activity and higher mean rumen pH values, the resulting effects are usually quite small. Grant et al. (1990) harvested alfalfa silage at three different cut lengths, although increasing chop length increased milk fat percentage by 0.8%, only a slight trend was observed in mean rumen pH. Although there is little evidence showing that forage cut length effects rumen pH and volatile fatty acid level, additional work should be carried out to determine how particle size may be important when feeding cows in different stages of lactation or in diets including varying levels on non-forage fiber sources. Additionally, if diets of coarse particle size result in an increased tendency of sorting, it is likely that even if mean rumen pH and VFA values are not different, diurnal patterns may be, resulting in a less consistent rumen environment.

Milk Production and Composition

In alfalfa based diets, forage particle size has been shown to significantly affect both yield and composition however most differences are reported when forage is in the dehydrated form (Woodford and Murphy 1988; Shaver 1986; Beauchemin et al., 1997). When forage is in silage form and different lengths of cut are fed differences have been observed in milk fat (Grant et al., 1990; Fisher et al., 1994; Shaver et al., 1996) and protein percentage (Beauchemin et al., 1994) but have not been observed in others (Armentano et al. 1988; Colenbrander et al., 1991).

Of the studies reviewed, none reported a significant response in milk production or fat corrected milk from feeding corn silage of different particle size (Clark and Armentano, 1999, Bal et al. 2000). Increasing milk protein with decreasing corn silage particle size has been observed in some studies and believed to be a result of increased starch and in essence, energy availability (Clack and Armentano, 1999). Fat percentage does not appear to be affected by feeding rations of different corn silage particle size (Clark and Armentano, 1999; Stockdale and Beavis, 1994) however, in one study in which coarse particle size resulted in excessive amounts of sorting and NDF refusal, milk fat was actually higher in rations of shorter particle size (Bal et al., 2000).

Although significant effects of particle size on TCA accompany effects on rumen pH (Grant et al. 1990; Shaver et al, 1988; Woodford and Murphy, 1986), differences are small and are not likely to result of the large shifts in volatile fatty acid production required to alter milk fat composition. Observed differences in composition are more likely to be a result of other factors such as passage and rate or extent of digestion.

Particle Size and Effective Fiber

Fiber is defined as the slowly digestible or indigestible organic fraction of the feed, which occupies space in the gastrointestinal tract (Mertens 1997). When an animal is deficient in fiber there is decreased chewing, resulting in less salivary buffer and a lower rumen pH and low acetate to propionate ratio, all factors affecting the animals overall performance and milk production. Yang et al. (2001) however noted that contribution of increased total daily saliva output due to increased TCA on rumen pH is often overestimated. Although reduced particle size may decrease TCA, changes in total saliva production are small (approximately 4%), as resting saliva secretion will increase.

It seems likely that the physical characteristics of the feed have a smaller influence on rumen pH than originally believed. In comparison, level of starch in the ration may have a greater effect on rumen pH and management of the ration nonstructural carbohydrate level may be more useful in identifying high-risk rations that lead to ruminal acidosis. It should be noted that to date there have been no controlled studies designed to evaluate the effects of feeding rations of different particle size on long term reproductive performance or health status (displaced abomasums, laminitis etc.) and that continually feeding high energy diets of fine particle size may have other negative effects

Particle Size Recommendations

Published studies are only beginning to report particle size distributions based on measurements of the PSPS thus making recommendations difficult. Current NRC recommendations state that a minimum mean particle length of 3 mm for alfalfa diets is necessary to maintain rumen pH, chewing activity, and milk fat percentage. Additionally, diet NDF content should be increased if excessively fine forages or high amounts of rapidly fermentable starch are fed. It is apparent that when silages are too coarse, sorting by the animals occurs at the feed bunk, this problem is further exacerbated when drier silages are fed. Refinement of these recommendations has been the subject of research by the author and recommendations based on controlled animal experiments and measurements using the PSPS should soon be available. Listed below are the current particle size recommendations for haylage and corn silage (Lammers et al. 1996). These may change in the future as more research data becomes available.

Particle size recommendations for haylage and corn silage based rations

Particle Fraction	Haylage TMR	Corn Silage TMR
> 19.0-mm	5-10	3-5
19.0-8.0-mm	30-35	45-55
< 8.0-mm	53 - 65	42-50

Table 1. The effect of alfalfa physical forage form on digestive parameters and milk production in lactating cattle (N/A denotes parameter not measured in study).

Reference	DMI ^x	Ruminating g ³ (min/d) ^y	DMD ^x	Acetate: Propionate ^x	pH ^{y,x}	Milk Yield	FCM ^x	% Protein ^x	% Fat ^x
Beauchemin et al. 1994	*	*	N/A	N/A	N/A	NS	NS	*	**
Yang et al. 2001	NS	N/A	NS	NS	NS	NS	**	*	*
Fischer et al. 1994	*	NS	N/A	NS	NS	NS	*	NS	*
Grant et al. 1990 b	NS	*	N/A	*	**	NS	*	NS	**
Woodford et al. 1986 ^z	NS	NS	NS	NS	NS	NS	NS	NS	NS

^x * = significant P < 0.05, NS = not significant P > 0.05

^y mean pH

^z study used three different chop lengths of alfalfa hay

Note: DMI= dry matter intake; DMD=dry matter digestibility; FCM=fat corrected milk

Table 2. The effect of corn silage physical forage form on digestive parameters and milk production in lactating cattle (N/A denotes parameter not measured in study).

Reference	DMI ^x	Ruminating (min/d)	DMD	Acetate: Propionate	pH ^y	Milk Yield	FCM	% Protein	% Fat
Bal et al. 2000	NS	NS	NS	NS	NS	NS	NS	NS	NS
Schwab and Shaver, 2001 ^z	NS	NS	N/A	N/A	N/A	NS	NS	NS	NS
Stockdale and Beavis, 1994	*	N/A	NS	NS	NS	NS	NS	NS	NS
Clark and Armentano 1999	NS	NS	N/A	N/A	N/A	NS	NS	NS	NS
Odai et al. 1988 a,b	NS	N/A	NS	NS	N/A	NS	NS	NS	NS

^x * = significant P < 0.05, NS = not significant P > 0.05

^y mean pH

^z combination of two abstracts published in the Journal of Dairy Science Vol 79: 199 and 349.

Note: DMI= dry matter intake; DMD=dry matter digestibility; FCM=fat corrected milk

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