

CHAPTER 6

GENERAL CONCLUSIONS

Dairy cattle require fiber to maintain normal rumen fermentation and function. Fiber consumed by the animal is mostly of forage origin however the use of byproducts may also be a valuable source of fiber. As rumen fermentation proceeds organic acids are produced and pH perceptibly falls. It is generally understood that rumination of consumed fiber stimulates saliva secretion and because saliva contains both bicarbonate and phosphate ions, is effective in maintaining a normal rumen environment. Current NRC (2001) recommendations state that a diet should contain a minimum of 25% NDF assuming alfalfa or corn silage as the predominate forage source and dry ground corn grain as the predominate grain source. Although this recommendation is generally accepted the effect of feeding rations of different particle size on chewing activity, and rumen fermentation is less understood but is needed for a more precise understanding of fiber requirements.

Sir Kenneth L. Blaxter once wrote that, "knowledge will always grow, and looking back it will always be possible for some to say that a particular attempt to translate scientific findings into practical procedures was premature, or rash, or ill conceived. Strangely enough, resistance to change also comes from those intimately concerned with experimental approaches. There is always one more experiment to be done, one more corollary to be explored, before the experimenter is willing to accept his [or her] hypothesis as reasonable approximations to the truth, and to think in terms of putting them to work.... the major lesson is that any new system should allow for growth within its framework, and provide ample latitude for minor or even major adjustments in the light of knowledge yet to come (Blaxter, 1967)." The intent of this work was not to be comprehensive view of particle size dynamics in lactating dairy cattle, but to initiate an empirical framework around the Penn State Particle Separator (PSPS), to guide the creativity of those applying its measurements, and lastly to challenge those focusing on further adjustments. This thesis presents three experiments, the first evaluates and more clearly specifies the use and operation of the PSPS. The remaining two experiments evaluate effects of ration particle size on

dairy cattle in early lactation. The primary objective of this thesis is to formulate ration physical recommendations that will strengthen current nutrient recommendations.

In the first experiment an additional sieve containing a pore size of 1.18 mm was developed and added to the sieve profile to more accurately describe sample fineness. Additionally the sieving movement was further described and the effects of sample moisture content were evaluated. To test the effect of shaking frequency on particle size measurement, samples of alfalfa haylage, corn silage, and a TMR were analyzed using three different frequencies: 0.9, 1.1 and 1.6 Hz and a 17 cm stroke length. We recommend the PSPS to be shook at a frequency of 1.1 Hz (66 cycles/min) or greater with a stroke length of 17 cm. To determine the effects of forage moisture level on particle size measurements, a samples of alfalfa haylage and corn silage were collected and partially dried at different times from 0 to 48 h to obtain samples of five different moisture contents. Small moisture loss from collected samples may affect particle size results but these differences, when observed are small. Conversely, completely drying a sample resulted in further size reduction during the sieving process and that different particle size results would be obtained.

A second experiment was conducted to determine the effect of feeding alfalfa haylage of particle size to cows in early lactation. Results of the experiment indicate that as particle size is reduced, intake may increase and that rechopping haylage increased DMI by 17.0%. Total (eating + ruminating) chewing activity (TCA) per kilogram of NDF consumed decreased 17.5% when rechopped forage was fed compared to that not rechopped. Highest DMD was observed on rations of shortest particle size (66.5%) and decreased linearly to with lowest DMD (63.1%) observed on diets of longest particle size. More specifically, apparent digestibility of CP, TNC, ether extract, NFC increased linearly and NDF and OM digestibility tended to increase linearly with decreasing particle size. Total concentration of VFA significantly increased linearly with reducing particle size with a 3.6% difference between longest and shorted ration. There was a quadratic effect observed for mean rumen pH with highest values observed in diets of intermediate particle size. Total milk yield, FCM, fat percentage and yield were not significantly affected by particle size reduction however a quadratic effect was observed for percent milk

protein but not yield. It is likely that although some loss in milk production may have been due to the cost of excess RDP, limits on milk production were likely a result of inadequate RUP.

A third and final experiment was conducted to determine the effects of feeding corn silage based diets of different particle size to cows in early lactation. Dietary treatments were four TMR's offered to cows in early lactation that differed in corn silage particle length (FPL) and cottonseed hull (CSH) inclusion rate (0 or 8% DM) designed to replace forage fiber. Although no effect was observed by feeding diets of different FPL, the inclusion of CSH resulted in higher DMI. Total (eating + ruminating) chewing activity (TCA) per kilogram of NDF consumed tended to increase with FPL and was reduced with the inclusion of CSH. The inclusion of CSH did not affect DMD but animals consuming rations of longer corn silage particle size exhibited a tendency to selectively consume more digestible particles and as a result longer these diets tended to have a higher DMD. Treatments effects on rumen fermentation were small and likely of limited biological significance. Although total VFA concentration was not affected by either FPL or inclusion of CSH high concentrations of propionate and ammonia in cows consuming diets containing CSH was likely a function of higher DMI and microbial activity. Milk yield and 3.5% FCM were similar across diets, averaging 48.5 and 48.1 kg respectively. Both percent and yield of milk protein was significantly higher for animals consuming shorter particle size. Increasing milk protein with decreasing corn silage is believed to be a result of increased starch digestibility as milk protein is positively correlated with dietary energy.

In summary reduction in ration particle size through either rechopping or the inclusion of a nonforage fiber source (NFFS) in rations containing a level of NDF meeting NRC requirements does not result in severe deleterious effects in rumen fermentation or milk production. In contrast, feeding rations of reduced particle size may be advantageous due to the positive effects on DMI observed in cows in early lactation and the potential negative effects observed with bunk sorting.

The primary objective of this thesis was to formulate particle size recommendations for dairy cattle fed a TMR. Table 6-1 contains the results of survey of commercial dairy farms that evaluated the particle size of corn silage, legume haylage, and TMR samples using the Penn State Particle Separator (PSPS) (Heinrichs et al., 1999). On average 8.1, 16.0 and 7.1% was

greater than 19.0 mm for corn silage, legume haylage and TMR respectively. Although these values are low, the coefficients of variation were all greater than 70 indicating high variability of this fraction. In comparison the proportion of material between 19.0 and 8.0 mm was higher (50.8, 40.5, and 35.2%) but coefficients of variation were lower than 35. Similarly the proportion of material < 8.0 mm was high (41.2, 43.5 and 57.7) but coefficients of variation were below 35 on all sample types. Together these results suggest that coefficients of variation in particle size fractions of 19.0 – 8.0 mm and < 8.0 mm on commercial dairy farms is between 21 and 30.

Table 6-2. contains the current particle size recommendations of corn silage, haylage, and TMR according to the Penn State Technical Bulletin, DAS 96-20 (1996). In formulating the recommendations surveys such as those of 6-1 were used, as experimental data was not available. The primary objective of this thesis work was to evaluate the effects of feeding diets of different particle size as described by the PSPS, and to evaluate the effects on intake, chewing activity, rumen fermentation and milk production. Because > 40% of sieved material has been observed to be less than 8.0 mm (Table 6-1) an additional smaller screen was added to the apparatus to result in a more precise measurement.

Although no recommendation may adequately apply to all feeding systems Table 6-3 contains particle size recommendations based on this thesis work. Both experiments two and three evaluated the effects of feeding a TMR of different particle size and as a result, corn silage and alfalfa haylage recommendations listed in Table 6-3 are an estimate of the required particle size necessary to yield listed TMR recommendations. The recommended amount of TMR \geq 19.0 mm was reduced from the original recommendation as no deleterious effects on rumen fermentation from reduced TCA were observed in rations containing less than 5% of the particles \geq 19.0 mm. The recommended amount of material between 8.0 and 19.0 mm was maintained and reflected the variation commonly observed on commercial dairy farms. As a result of the modification of the PSPS particle size recommendations of material < 8.0 mm is now further partitioned into the proportion between 1.18 and 8.0 mm and the proportion < 1.18 mm. Given that no severe negative effects were observed in animals consuming rations with 30 – 50 percent of the ration or recommendations are limited to that range. Although the proportion of material >

1.18 mm was not different within experiments, we did not observe any negative effects when > 20% of the material less than 1.18 mm. As a result we are thus limited to recommend that TMR's contain no more than 20% of the material < 1.18 mm.

To date there is ample evidence to demonstrate that ration physical form affects chewing activity, rumen fermentation and milk production and composition. The next area of study should;

- 1) determine the degree of rumination stimulated by different size fractions of the PSPS
- 2) evaluate the effectiveness of different particle size distributions at NDF and NSC levels above and below recommended levels
- 3) evaluate different grain particle size on rumen pH and starch utilization on measurements according to the modified PPS.

REFERENCES

Blaxter, K.L. 1967. The energy metabolism of ruminants. Hutchinson Scientific and Technical. London England.

Table 6-1. Mean percentage, standard deviation, and coefficients of variation in three particle size fractions of corn silage, legume haylage and TMR samples as measured by the Penn State Particle Separator (Heinrichs et al., 1999).

	Type								
	Corn Silage ¹			Legume Haylage ²			TMR ³		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
% retained									
> 19.0 mm	8.1	6.4	79.0	16.0	11.6	72.5	7.1	5.4	76.1
19.0 – 8.0 mm	50.8	12.3	24.2	40.5	11.0	27.2	35.2	10.6	30.1
< 8.0-mm	41.1	14.1	34.3	43.5	13.8	31.7	57.7	12.2	21.1

¹ n = 5,395

² n = 2,815

³ n = 831

Table 6-2. Recommended forage and TMR particle size recommendations as measured by the Penn State Particle Separator.

	Type		
	Corn Silage ¹	Haylage ²	TMR
% retained			
> 19.0 mm	2 - 4	15 - 25	6 - 10
19.0 – 8.0 mm	40 - 50	30 - 40	30 - 50
8.0 – 1.18 mm	40 - 50	40 - 50	40 - 60

¹ this recommendation applies if corn silage is not the sole forage used in the TMR, if chopped and role 10 – 15% may be > 19.0-mm.

² this recommendation applies if haylage is contained in a bunker silo, if in a sealed silo 10 – 15% may be > 19.0-mm.

Table 6-3. Forage and TMR particle size recommendations¹ based on 2 experiments that fed either alfalfa haylage or corn silage, with or without cottonseed hulls to cows in early lactation.

	Type		
	Corn Silage	Haylage	TMR
% DM retained			
> 19.0 mm	5 ± 3	15 ± 5	5 ± 3
19.0 – 8.0 mm	55 ± 10	60 ± 15	40 ± 10
8.0 – 1.18 mm	40 ± 10	30 ± 10	40 ± 10
< 1.18 mm	< 5	< 5	≤ 20
X_{gm} (mm) ²	8 ± 2	10 ± 2	5 ± 2
S_{gm} (mm) ³	2 ± 1	2 ± 1	3 ± 1

¹ As measured by the Penn State Particle Separator (Kononoff et al., 2002).

² X_{gm} = geometric mean length as calculated by the ASAE (2001)

³ S_{gm} = standard deviation as calculated by ASAE (2001)

APPENDIX A.

PARTICLE SIZE MEASUREMENT OF THREE FORAGE TYPES AND EVALUATION OF SIEVED FRACTIONS

APPENDIX A. Table 1. Neutral detergent fiber and dry matter digestibility (DMD) of corn silage, mixed mostly grass and mixed mostly legume forage samples.

	Corn Silage	Mixed Mostly Grass	Mixed Mostly Legume
Number of samples	11	15	21
Minimum NDF	31.61	37.27	38.35
Mean NDF	41.09	51.73	46.81
Maximum NDF	53.93	63.32	58.35
Minimum DMD	56.37	46.28	46.70
Mean DMD	64.36	58.79	59.53
Maximum DMD	70.59	71.88	71.08

APPENDIX A. Table 2. Particle size distribution, neutral detergent fiber concentration, and in vitro dry matter digestibility (DMD) for corn, mixed mostly grass, and mixed mostly legume silages.

Means for fractions	Forage Type ¹		
	CS ²	MMG ²	MML ²
Percent Retained			
19.0 mm	8.06	14.78	15.34
8.0 mm	59.06	47.67	42.00
Pan	32.88	37.55	42.66
NDF by sieve			
19.0 mm	63.27 ^a	56.27	52.76 ^a
8.0 mm	40.73 ^b	51.60	47.10 ^b
Pan	38.73 ^b	50.53	44.91 ^b
SEM	2.08	2.34	1.2
DMD by sieve			
19.0 mm	58.0 ^b	62.09	64.27
8.0 mm	67.73 ^a	64.46	66.47
Pan	66.04 ^a	62.93	64.63
SEM	1.75	1.87	1.29

¹ CS = corn silage, MMG = mixed forage but mostly grass, MML = mixed forage but mostly legume

² a,b means of the same forage type in the same column and different letters are different ($P \leq 0.05$)

APPENDIX B

THE EFFECT OF REDUCING ALFALFA HAYLAGE PARTICLE SIZE ON
ORT COMPOSITION AND RUMEN pH

APPENDIX B. Table 1. Effects of reducing alfalfa haylage particle size on the chemical composition of orts on cows in early lactation.

	Treatment ¹				SEM	Contrast		
	SH	MSH	MLG	LG		Linear	Quadratic	Cubic
Orts								
OM, %	91.0	90.0	89.8	90.1	0.66	0.31	0.39	0.91
CP, %	18.4	16.3	17.7	18.1	0.66	0.62	0.26	0.05
NDF, %	29.1	28.7	29.6	30.1	1.29	0.19	0.43	0.90
ADF, %	17.0	17.3	17.5	17.9	1.24	0.41	0.99	0.94
TNC, %	33.6	31.1	35.8	31.5	2.51	0.88	0.75	0.11

¹ SH = TMR containing short alfalfa haylage, LG = TMR containing long alfalfa haylage, MSH = TMR composed of 1/3 parts LG, 2/3 parts SH TMR, MLG = TMR composed of 2/3 parts LG, 1/3 parts SH TMR.

APPENDIX B. Table 2. Effects of reducing the particle size of alfalfa haylage on ruminal pH on cows in early lactation.

	Treatment ¹				SEM	Contrast		
	SH	MSH	MLG	LG		Linear	Quadratic	Cubic
Mean	6.04	6.15	6.13	6.09	0.08	0.28	<0.01	0.46
Variance	0.09	0.09	0.07	0.09	0.01	0.69	0.34	0.57
Maximum	6.53	6.61	6.60	6.57	0.06	0.67	0.44	0.82
Minimum	5.62	5.69	5.74	5.69	0.06	0.31	0.33	0.74
Range	0.91	0.92	0.86	0.88	0.08	0.34	0.15	0.34
AUC ²	147.7	148.7	149.6	146.6	1.53	0.62	0.08	0.47

¹ SH = TMR containing short alfalfa haylage, LG = TMR containing long alfalfa haylage, MSH = TMR composed of 1/3 parts LG, 2/3 parts SH TMR, MLG = TMR composed of 2/3 parts LG, 1/3 parts SH TMR.

² AUC = area under the curve

APPENDIX C.

THE EFFECT OF CORN SILAGE PARTICLE SIZE AND COTTONSEED HULLS ON
ORT COMPOSITION AND RUMEN pH

APPENDIX C. Table 1. Effects of forage particle length (FPL) and fiber source (FS) on chemical composition of orts on cows in early lactation.

	Treatment ¹				SEM	Contrast		I ²
	LGNH	LGH	SHNH	SHH		FPL	FS	
Orts,								
OM, %	95.1	94.1	93.4	93.7	0.18	< 0.01	0.09	0.02
CP, %	13.6	13.5	15.8	17.0	0.99	0.04	0.61	0.55
NDF, %	50.6	44.5	33.9	36.2	1.9	< 0.01	0.35	0.08
ADF, %	27.5	27.0	20.1	21.7	1.2	< 0.01	0.67	0.40
TNC, %	30.1	28.9	27.3	29.5	1.7	0.18	0.70	0.06
NFC, %	26.6	31.9	39.5	36.5	1.3	< 0.01	0.42	0.02
EE, %	4.23	4.13	4.09	4.09	0.19	0.43	0.73	0.66

¹LGNH = TMR with long corn silage, no cottonseed hulls, LGH = TMR with long corn silage and cottonseed hulls, SHNH = TMR with short corn silage and no cottonseed hulls and SHH = TMR with short corn silage with cottonseed hulls.

²FPL X FS interaction

APPENDIX C. Table 2. Effects of forage particle length (FPL) and fiber source (FS) on rumen pH on cows in early lactation.

	Treatment ¹				SEM	Contrast		
	LGNH	LGH	SHNH	SHH		FPL	FS	I ²
Mean	6.24	6.16	6.24	6.17	0.09	0.98	0.05	0.88
Variance	0.17	0.17	0.21	0.14	0.03	0.82	0.22	0.18
Maximum	6.90	6.76	6.97	6.72	0.10	0.76	0.03	0.28
Minimum	5.69	5.59	5.65	5.69	0.08	0.50	0.67	0.13
AUC ³	150.9	149.4	149.8	149.4	2.07	0.65	0.60	0.64

¹LGNH = TMR with long corn silage, no cottonseed hulls, LGH = TMR with long corn silage and cottonseed hulls, SHNH = TMR with short corn silage and no cottonseed hulls and SHH = TMR with short corn silage with cottonseed hulls.

²FPL X FS interaction

³AUC = area under the curve