Unlock forage potential with precision chewing management

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Notes:
Paper and PowerPoint Slides on following pages

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Optimizing the relationship among eating, resting, and ruminating time is critical for precise and efficient feeding of dairy cattle. Key components of the management environment - such as feed availability, stall comfort, and stocking density, to name a few – affect all three of these behaviors. Forages and dietary fiber also play a key role with their effect on chewing, both at the feed bunk while eating and during rumination. Precision chewing management aims to optimize eating and ruminating while lying down (i.e., recumbent rumination) to boost dry matter intake and healthy production of milk components. The focus is on forage fiber digestibility and particle size combined with the feeding environment. Unlocking the nutritional potential forage demands this overarching focus on cow comfort and forage quality.

Fundamental balance between eating and recumbent rumination time

Natural, healthy feeding behavior (meal bouts, eating rate, meal length) dictates that cows should spend between 3 and 5 hours daily eating. Forage or management factors that drive a cow to spend more than about 5 hours per day eating often result in the cow running out of time to eat thereby reducing dry matter intake, sacrificing resting time, or both. In fact, a 1:1 trade-off between excessive eating time (greater than about 300 minutes/day) and reduced resting time exists for dairy cattle. And when resting time drops, all-important rumination while lying down necessarily declines.

Forage-fiber characteristics affect eating time, and too much dietary fiber, poor fiber digestibility, excessive undegradable fiber, and(or) too-long particle size force the cow to spend too much time eating. A key insight is that particle size of the ration is not the particle size in the swallowed bolus. For many rations, regardless of the ration particle size, the swallowed bolus particle size is much more uniform and about 8 to 12 mm in length. This size is essentially the same as the second sieve of the Penn State Particle Separator. At Miner Institute, we have measured up to a 6-fold reduction in long particle length before a bolus of feed is swallowed while eating. This reduction in size requires longer eating time at the feed bunk. So, when cattle are fed rations with too much coarse forage, eating time increases and at the same time intake drops. Rumination is less affected because the cow is populating the rumen with a fairly consistent particle size of feed.

Precision management of forage and ration particle size aims to make eating easy for the cow. That means chopping forages and mixing rations that are enriched with the fraction of particles retained on the second tier of the Penn State Particle Separator. These particles, along with those on the 4-mm sieve (i.e., third tier), stimulate rumination effectively but can also be easily eaten and swallowed by the cow (Grant, 2024).

Recent research demonstrates that cows who ruminate more while lying down have higher rumen pH, consume more dry matter, and yield milk with higher percentages of fat and protein. At Miner Institute we observed a positive correlation between rumination while lying down and milk fat percentage. The bottom line is that cows may have similar rumination time, but those that ruminate more while lying down eat more and produce milk with more fat and protein. The fundamental importance of recumbent rumination is clear. Consequently, we must ensure that forage and feeding management allow the cow sufficient time to lie in a comfortable stall or resting place and engage in the all-important recumbent rumination.

Recommended particle size for precision chewing

Recommended chop lengths for total mixed rations and forages that allow the cow to achieve optimal chewing activity have been published by Grant and Cotanch (2023). We propose a sliding scale for theoretical length of chop between approximately 3/8 to ¾ of an inch (12 and 22 mm). Below this range faster passage rates from the rumen may reduce feed efficiency. Above this range, the risk of sorting ramps up. Within the typical range, the optimal length of chop can be adjusted based on factors such as maturity at harvest, fragility of the crop, and moisture content. For example, as haycrop matures, cut it finer. Drier, more fragile alfalfa should be chopped coarser. Likewise, highly digestible and fragile brown midrib corn silage should be chopped coarser. As corn silage matures and drops in moisture, chop it finer. This is a dynamic approach to adjust particle size to complement forage characteristics to maintain physically effective undegraded fiber within a range associated with optimal dry matter intake (~4 to 6% of ration DM; Grant, 2023; Grant and Cotanch, 2023).

Precision chewing management

The following description of precision chewing management is taken from Grant (2024): "Precision chewing management allows every cow to achieve the proper balance between eating time and recumbent rumination. Eating time is optimized by feeding management that ensures feed availability 24/7, pushed up within easy reach. The ration itself should have particle size, fiber digestibility, and forage content to allow consumption within 3 to 5 hours. The particle size of the feed should be enriched with those on the 8-mm sieve of the Penn State Particle Separator to avoid excessive eating time while stimulating ample rumination. Finally, the feed and management environment should allow comfortable resting for 11 to 12 hours daily with 80% or more of rumination time occurring while lying down. Precision chewing management ensures optimal dry matter intake, a healthy rumen, and efficient production of milk fat and protein."

References

Grant, R. J. 2023. What we've learned from cows: A tale of two decades of management research at Miner. Proc. 2023 Cornell Nutr. Conf. Feed Manufac., East Syracuse, NY.

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Member, Board of Trustees
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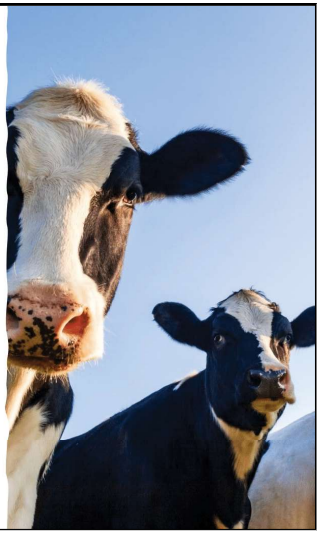
Successfully balancing eating, resting, and ruminating time is critical for precise and efficient feeding of dairy cattle…
Herd management + forage fiber **play a key role with their effect on chewing…**

"Precision Chewing Management"

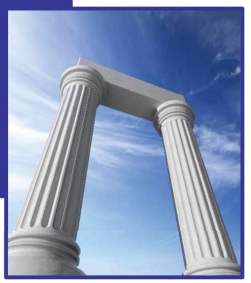


Cow Management and Forage Fiber*

Eating time	Resting/ruminating time
3-5 h/d	12-14/8-9 h/d

*NDF%, NDFD, uNDF, particle size

Cow Comfort and Forage Quality need to be a System!



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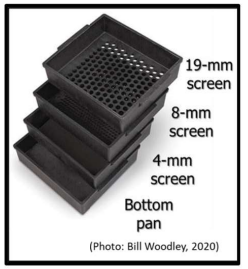
Fundamental forage concepts

- Economic, environmental, and social considerations are encouraging use of higher fiber diets (Martin et al., 2017).
  - Forage and non-forage
- NDF alone does not explain all observed variation in DMI and milk yield as dietary source and content vary.
- **Incorporate measures of degradability and particle size.** peNDF / pef x uNDF240

Rethinking fiber degradability and particle size…

- Value in integrating forage (un)degradability and particle size to better predict DMI
  - uNDF240 x physical effectiveness factor (pef) = peuNDF240
    - peuNDF240 tracks with DMI, ECM, chewing, and rumen pH better than uNDF240 alone (Smith et al., 2019).
  - *Dynamically* adjust particle size:
    - As forage matures (i.e., NDF digestibility declines) chop finer and vice versa.
    - Growing seasons that enhances lignification – be proactive, chop finer.
  - ***Boost dry matter intake*** by up to 5 lb/d…still must consider rumen turnover and feed efficiency



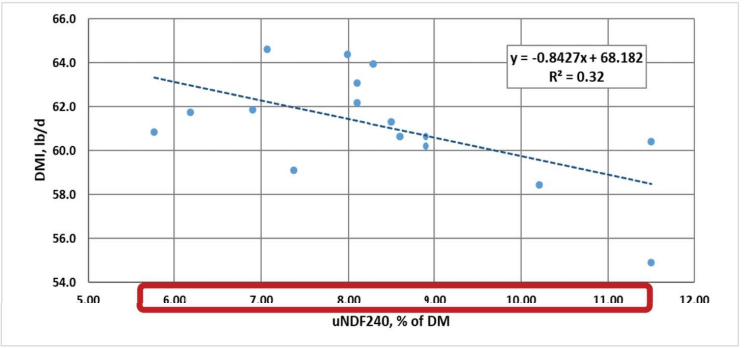
Dietary uNDF and particle size: Feed intake and eating behavior

	Low uNDF240 (8.8% of DM)		High uNDF240 (11.5% of DM)	
Item	Low peNDF (20%)	High peNDF (22%)	Low peNDF (19%)	High peNDF (22%)
peuNDF240, % of DM	5.4	5.9	5.9	7.1
DMI, lb/d	60.5	60.1	60.3	54.8
Eating time, min/d	255^{b}	263^{b}	279^{ab}	300^{a}
Meal length, min	27.7^{c}	32.8^{b}	32.6^{b}	37.7^{a}
Meal bouts, /d	11.3^{a}	10.5^{ab}	10.7^{ab}	10.0^{b}

^{abc} Within a row different superscripts differ ($P \leq 0.05$).

✓ Greater intake and more meals with lower uNDF240 diets, *and high uNDF240 diet chopped shorter.*

Dietary uNDF240 and DM Intake



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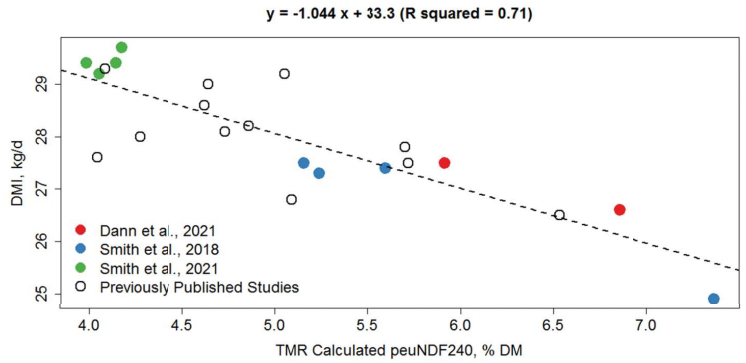
Updated Database: peuNDF240 versus DMI

(Farricker et al., 2022)



Dynamic particle size complements fiber degradability

- Appears to be value in integrating two measures of fiber - uNDF240 and pef - when formulating rations based on corn silage and hay or haycrop silage…perhaps alfalfa
- Forage testing laboratory data report range of 3 to 9% peuNDF240
- Miner database: 4 to 7% peuNDF240
  - Considerable effects on DMI across this range…
  - Optimal ~4 to 6%
- **Use this dynamic particle size concept to optimize relationship between eating and recumbent rumination!**

Cow Management and Forage Fiber*

Eating time 3-5 h/d

Resting/ruminating time 12-14/8-9 h/d

*NDF%, NDFD, uNDF, particle size

Behavior responses to increasing diet forage content (Jiang et al., 2017)

Item	40%	50%	60%	70%	Difference
DMI, lb/d	49.3	47.3	44.7	41.1	-8.2 lb/d
Eating, min/d	286	292	342	393	+107 min/d
Rumination, min/d	426	454	471	461	+35 min/d
Total chewing, min/d	712	745	813	853	+141 min/d
Resting, min/d	728	695	627	587	-141 min/d

- ✓ Corn silage, alfalfa, alternative forages.
- ✓ Increased chewing time (mostly longer eating time) at expense of resting time.
- ✓ Eating time 3-5 h/d encourages natural feeding behavior (Grant and Albright, 2001).

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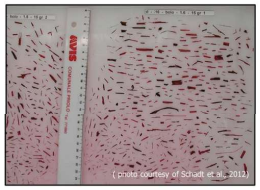
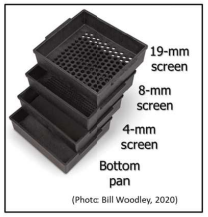
- **Particle size of the ration is not the particle size of swallowed bolus.**
  - **Bolus particle size is more uniform**
  - **Up to a 6-fold reduction in particle size during eating**
  - **~8-12 mm in swallowed bolus**
    - **Particles retained on 8-mm sieve of PSPS**





Particle size of ingested feed

(Schadt et al., 2011)

Forage type	NDF, % of DM	Feed size, mm	Bolus size, mm	Chews, /g NDF
Long rye grass hay	57.1	…	10.3	2.6
50-mm rye hay	58.6	42.2	9.9	3.5
19-mm PSPS hay	57.9	43.5	10.7	2.2
8-mm PSPS hay	59.1	25.1	10.8	1.7
1.18-mm PSPS hay	54.2	9.7	8.1	1.9
Grass silage	53.1	13.8	11.6	0.4
Corn silage	46.1	12.0	11.2	0.7
TMR	37.7	13.1	12.5	0.6

Recumbent rumination boosts intake and milk components

- **Cows with greater ruminating while lying down:**
  - **Have higher rumen pH**
  - **Consume more DM**
  - **Produce milk with greater fat, protein %**
- **Miner study (2023, unpublished):**
  - **Holsteins, 3.2 to 6.4% milk fat**
  - **Of all behaviors, strongest positive correlation was between rumination while lying and milk fat**

(Campbell and Grant, 2017; McWilliams et al., 2021)

Avoid too-long particles…

- **TMR particles retained on 19-mm sieve of PSPS most likely to be sorted.**
  - **Associated with greater variation in chewing, rumen pH, DMI and milk yield in early lactation**
  - **% particles on 19-mm sieve negatively associated with DMI, ECM, and milk fat%.**
- **Herds with highest milk fat %**
  - **>50% of TMR particles on 8-mm sieve!**
- **Particles retained on 8-mm sieve more effective at stimulating chewing than particles on top sieve!**

(Kononoff et al., 2003; McCarthy et al., 2018; Filho et al., 2023; Ferraretto et al., 2024)

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If particle size is finer than cow would naturally swallow in feed bolus while eating?

- It may be hard to boost rumination with longer particle size, but we can depress it by chopping more finely than the cow.
- **Bottom line**: ensure that ration particle size is not less than the cow would create herself.
  - Goal is attaining eating time between 3 and 5 h/d, NOT minimizing it!

Particle size recommendations to optimize cow behavior…

Suggested PSPS targets:

Miner Institute (Cotanch, 2017; rev. 2020)

	Sieve mm	PSPS 2013 %	Miner 2020 %	Comments
Top	19	2-8	2-5	Sortable material, too long, increases time needed for eating; especially if >10%. *Length of 1 to 2 inches maximum.*
Mid 1	8	30-50	>50	Still long and functional pef, more so than 4 mm material. *Maximize amount on this sieve, 50-60%*
Mid 2	4	10-20	10-20	Functions as pef sieve, no recommendation for amount to retain here other than total on the top 3 sieves = pef
Pan	---	30-40	25-30	40-50% grain diet results in at least 25-30% in the pan

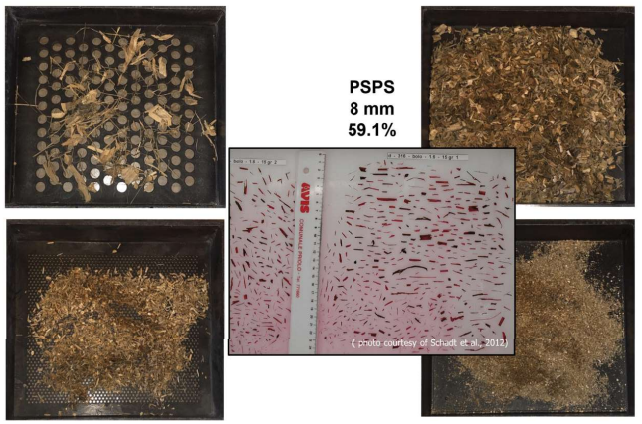
✓Keep feed in front of cow
✓Comfortable stalls
✓Part of a system

TMR from Miner Institute herd:
~100 lb/d milk with 4.3% fat and 3.1% true protein

PSPS 19 mm 4.2%

PSPS 8 mm 59.1%

PSPS 4 mm 11.3%



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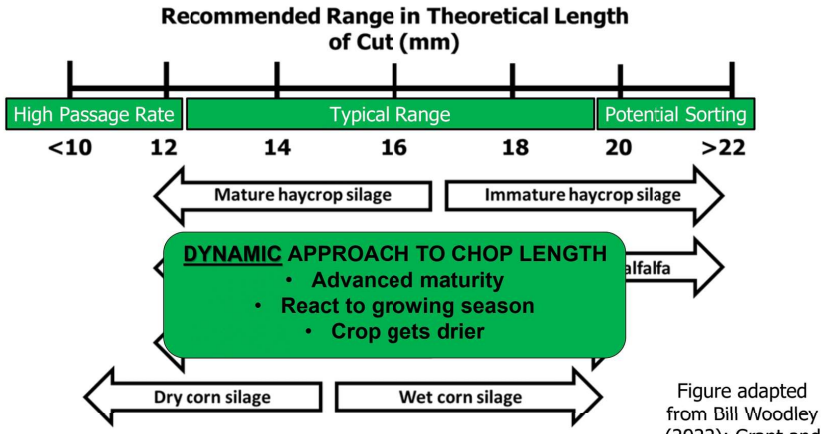

1 inch = 2.54 cm

Figure adapted from Bill Woodley (2022); Grant and Cotanch (2023)

Think about potential for further particle size reduction…

- What silage/forage handling and mixing techniques occur?
  - Silage removal, defacer
  - Mixer knife sharpness
  - Mixing time
  - Others…

Recommended PSPS distributions: Miner Institute - work in progress				
Screen (mm)	TMR	Corn silage	Alfalfa silage	Grass silage
19 mm	< 5	3 to 8	5 to 15	5 to 15
8 mm	>50	50 to 65	50 to 75	50 to 75
4 mm	10 to 20	30 to 40	25 to 30	20 to 30
Pan	25 to 30	< 5	< 5	< 5

✓ Based mainly on feedback from nutritionists in the field.

✓ Considerable variation between TLC and silage particle size distribution.

✓ GOAL: chop length should ensure good packing in silo to reduce DM losses.

Alfalfa haycrop silage

Corn silage

(Photos kindly provided by Tony Hall, Lallemand; Bill Woodley, 2023)

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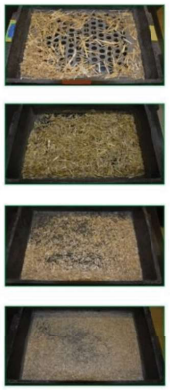
Straw and Hay Particle Size to Minimize Sorting



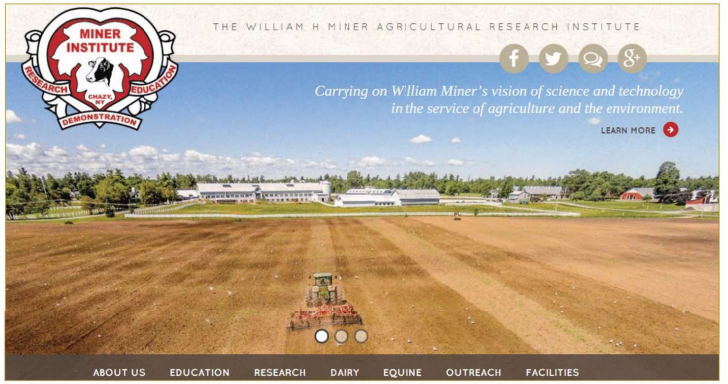
(Dann, 2023)

Ideal situation for Precision CHEWING Management

Right forage to right cows Manage starch x NDF	Particle size, uNDF, NDFD, and forage % (4-6% peuNDF240) to allow 3 to 5 h/d eating time	Populate rumen with 2nd screen (8 to 12 mm) of PSPS • >50% of TMR • no excessive eating time, stimulates rumination
Comfortable stall availability to encourage recumbent rumination	Feed available 24/7 and pushed up!	Heat abatement and free access to water

"Cows that ***aren't rushed while eating,*** have ***freedom to lie down and ruminate,*** ***and can strike proper balance between eating and recumbent rumination,*** will have ***optimal rumen conditions*** for fiber digestion and healthy production of ***more milk components.***"

Carrying on William Miner's Vision: "Science in the Service of Agriculture."



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Ration fiber guard rails…use them properly!

- 30-h NDFD
  - >50% for legumes
  - >60% for grasses
  - >60% for corn silage (65% for bmr)
- uNDF240 > 10% of DM, decrease DMI
  - Consider finer chop length
- peuNDF240: 4.5 to 6.0% of DM
- uNDF240 < 7% of DM, decreased rumen pH and increased risk of milk fat depression
  - Keep peNDF at least 19 to 20% of ration DM…alfalfa hay?
- RFS:uNDF240 > 2.8, greater risk of MFD
  - When uNDF240 ≤7% of DM, be careful!

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