Effects of particle size of total mixed rations on intake, chewing activity, rumen digestion and milk production in dairy cows

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Introduction

Need for higher levels of energy = diets high in concentrates

Shortage of fiber levels: forage of short particle size:

• reduced milk fat percentage
• displaced abomasum
• rumen parakeratosis
• laminitis, or rumen acidosis

• chewing activity
• saliva flow
• rumen pH
• acetate-to-propionate ratio
Feed Factors Affecting Chewing Activity

- Chemical Structure
- Physical Structure
- Nonforage Fiber Sources (NFFS)
- Passage Rate and Particle Size
Table 2-1. Minimum diet and forage NDF, and maximum NFC (% DM) requirements of dairy cattle fed total mixed rations (NRC, 2001).

<table>
<thead>
<tr>
<th>Minimum Forage NDF</th>
<th>Minimum Dietary NDF</th>
<th>Maximum Dietary NFC&lt;sup&gt;1&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>25</td>
<td>44</td>
</tr>
<tr>
<td>18</td>
<td>27</td>
<td>42</td>
</tr>
<tr>
<td>17</td>
<td>29</td>
<td>40</td>
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<tr>
<td>16</td>
<td>31</td>
<td>38</td>
</tr>
<tr>
<td>15</td>
<td>33</td>
<td>36</td>
</tr>
</tbody>
</table>

<sup>1</sup> Because of the limited data available on direct non-structural carbohydrate (NSC) measurements and requirements, nonfiber carbohydrate (NFC) was calculated by difference: 100 - (% NDF + % CP + % Fat + % Ash) (G.A. Varga, personal communication).
Materials and methods

• Measurement of physical effective NDF (peNDF)

dietary fiber source which effectively stimulates rumination and salivation

• The Penn State Particle Separator (PSPS)

  Lammers et al., 1996 → PSPS with 2 sieve: 19.0 and 8.0 mm

  Kononoff et al., 2003 → PSPS with 3 sieve: 19.0 and 8.0 and 1.18
PeNDF (%) = (DM % > 19mm × NDF % > 19mm) + (DM % > 8 mm × NDF % > 8 mm) + (DM % > 1/18 mm × NDF % > 1/18 mm)
• Measurement of chewing activity
  
  o Visual observation
  
  o Electronic recordings

http://www.ultrasoundadvice.co.uk/pages/IGERhome.html
Figure 2. Transducer attached to leather halter.
Figure 2-2. An example of the Graze window and recorded eating movements resulting in wave like patterns.
Figure 2-3. An example of the Graze window and recorded ruminating movements in which the wave like patterns separated by brief inactivity marking the movement of boli.
Results and discussion

**Effects of particle size on feed intake**

- DM intake responded poorly, negatively, to FPL
- DM intake is influenced by:
  - Rates of digestion
  - Rates of passage
- The effect of dietary particle size on DM intake:
  - Forage source
  - Forage to concentrate ratio
  - Type of concentrate
Effects of particle size on chewing activity

- Chewing and rumination (min/24 h) correlated to FPL and FNDF
- Particle size for maize silage 4.8 mm, for grass silage was 2.8 mm
- Mean chewing time per kg DM ingested equal to 30 min/kg
RP = $57.50 - 4.70 \times PLI_3 - 0.26 \times FNDF + 1.52 \times NDFI$

TCT = $544.6 + 159.9 \times PLI_2 + 317.1 \times PLI_3 - 12.1 \times DMI + 9.2 \times FNDF$

TCA (minutes per kilogram of DM) = $-97.1 + 3.10 \times [%\text{NDF}]$

TCA (minutes per kilogram of NDF) = $1.5 + 2.37 \times [%\text{NDF}]$

Chewing/kilogram of peNDF = $248.0 - 5.09 (\text{kilogram of DMI})$.

RP = ruminating time, percentage of total chewing time,
NDFI = NDF intake (kilograms per day)
PLI = particle length index ($PLI_3 = -0.2145$), ($PLI_2 = 0.0519$)
TCT = total chewing time
TCA = Total chewing activity
Effects of particle size on rumen fermentation

• Ruminal pH was affected by FPL and NDF content

• The acetate to propionate ratio was positively affected by dietary NDF

• Forage particle size affects chewing activity more than ruminal pH.

• Intake of peNDF equal to 4.4 and 4.1 kg/d = mean rumen pH of 6.0.
Ruminal pH = 3.98 + 0.011 * NDF + 0.040 * OMI + 0.031 * FNDF + 0.18 * PLI2 – 0.15 * PLI3

Ruminal pH = 8.38 + 1.91 * PLI2 + 0.38 * PLI3 – 0.088 * RDOMP + 0.067 * NDF – 0.258 * OMI + 0.499 * RDOMKG – 0.060 * PLI2 * NDF – 0.014 * PLI3 * NDF

Daily mean ruminal pH = 1.92 (± 0.163) + 0.745 (± 0.029) × nadir pH

OMI = OM intake (kilograms per day)
FNDF = forage NDF (percentage of DM)
RDOMP = ruminally degraded OM (percentage of total OM)
RDOMKG = ruminally degraded OM (kilograms per day)
Figure 4. The relationship between mean ruminal VFA concentration and mean ruminal pH from experiments reported in the literature using ruminally cannulated, lactating dairy cows with ruminal pH reported as within-day means. Ruminal pH = 6.56 - 0.0049 × VFA (millimoles per liter); \( P < 0.001 \); \( r^2 = 0.13 \); root mean square error = 0.23; \( n = 99 \) (1, 8, 9, 11, 12, 17, 18, 19, 21, 27, 28, 31, 40, 42, 59, 60, 61, 62, 64, 67, 75, 80, 82, 84, 101).
Effects of particle size on fiber digestibility

- NDF digestibility related to FPL and NDF
- No relationship between digestibility of DM and FPL
- Dietary particle length enhance ruminal fermentation:
  - barley-based diets
  - processed CS rather than unprocessed CS
- Increase dietary peNDF:
  - Increased intestinal flow of microbial N (g/d)
  - Increased microbial efficiency (g/kg of digestible OM intake)
• The FPL did not affect ruminal passage rate

• The lack of effect of FPL on passage rate and digesta mass consistent with results of DM intake

increased chewing activity
Effects of particle size on milk production and milk contents

- The FPL did not correlate with milk production and milk content
  Because of enough level NDF and FNDF

- Milk fat:protein ratio increased with increasing peNDF > 1.18
Conclusions and implications

<table>
<thead>
<tr>
<th>factor</th>
<th>measure</th>
<th>effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>peNDF</td>
<td>31.2%</td>
<td>Minimize the risk of SARA</td>
</tr>
<tr>
<td>peNDF/RDSG</td>
<td>1.45</td>
<td></td>
</tr>
<tr>
<td>Long forage</td>
<td>7%</td>
<td></td>
</tr>
<tr>
<td>Chewing time</td>
<td>36.5 min/kgDM</td>
<td>Milk fat = 3.6%</td>
</tr>
<tr>
<td>Chewing time</td>
<td>30 min/kgDM</td>
<td>Minimize the diseases</td>
</tr>
<tr>
<td>peNDF eating</td>
<td>4.1 to 4.6 kg/DM</td>
<td>pH = 6</td>
</tr>
</tbody>
</table>
In conclusion, a level of about 30 to 33% peNDF in the diet may be considered generally optimal for minimizing the risk of SARA without impairing important production responses in high-yielding dairy cows.
Table 1. Forage and TMR particle size recommendations based on three experiments using early lactation cows fed either alfalfa haylage or corn silage with or without cottonseed hulls.

<table>
<thead>
<tr>
<th>Screen</th>
<th>Pore Size (inches)</th>
<th>Particle Size (inches)</th>
<th>Corn Silage</th>
<th>Haylage</th>
<th>TMR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Sieve</td>
<td>0.75</td>
<td>&gt; 0.75</td>
<td>3 to 8</td>
<td>10 to 20</td>
<td>2 to 8</td>
</tr>
<tr>
<td>Middle Sieve</td>
<td>0.31</td>
<td>0.31 to 0.75</td>
<td>45 to 65</td>
<td>45 to 75</td>
<td>30 to 50</td>
</tr>
<tr>
<td>Lower Sieve</td>
<td>0.05a</td>
<td>0.07 to 0.31</td>
<td>30 to 40</td>
<td>20 to 30</td>
<td>30 to 50</td>
</tr>
<tr>
<td>Bottom Pan</td>
<td>&lt; 0.07</td>
<td>&lt; 0.07</td>
<td>&lt; 5</td>
<td>&lt; 5</td>
<td>&lt; 20</td>
</tr>
</tbody>
</table>

*Pores are square, so largest opening is the diagonal, which is 0.07 inches. This is the reason the largest particles that can pass through the Lower Sieve are 0.07 inches in length.
References

Thanks for your attention