Managing for gut health

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University of Saskatchewan
Take-home messages

- A consistent supply of DM and nutrients are required to maintain gut health
- Production responses have not been well characterized but can be extrapolated
- Management strategies to minimize variation in intake may yield greatest rewards
- Recovery following a challenge takes time, but can be accelerated
Requirements of the gastrointestinal tract

- Absorptive and secretory
  - Supply energy
  - Regulates ruminal pH
  - Urea recycling

- Barrier
  - First arm of the immune response
  - Prevents pathogen and antigen translocation

- Communicative
  - Facilitates cross-talk between host and microbiota
  - Nutrient sensing
Why is there variation in rumen pH?

Penner et al., 2009
Greater absorption reduces risk for low pH

Peptide concentration, nmol/(mg protein \times min)

P < 0.05

- Control
- Resistant
- Susceptible

Penner et al., 2009
Barrier function

- Ability to promote selective permeability
  - Allow absorption of nutrients
  - Prevent movement of non-desired compounds, toxins, enteric flora

- Damage occurs in two forms
  - Lesions
  - Compromised tight-cell junctions
Barrier function

(a) **Tight junctions**: Impermeable junctions prevent molecules from passing through the intercellular space.

(b) **Desmosomes**: Anchoring junctions bind adjacent cells together like a molecular “Velcro” and help form an internal tension-reducing network of fibers.

(c) **Gap junctions**: Communicating junctions allow ions and small molecules to pass for intercellular communication.
Evidence supporting stability in the rumen microbial community structure
Gut health is more than just the rumen

Gorka et al., 2017

<table>
<thead>
<tr>
<th>Region</th>
<th>Length, m</th>
<th>Total Length (m)</th>
<th>Total Length (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duodenum</td>
<td>0.53</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jejunum</td>
<td>21.62</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ileum</td>
<td>0.80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cecum</td>
<td>0.22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colon</td>
<td>4.63</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>27.80</strong></td>
<td></td>
<td><strong>91.2</strong></td>
</tr>
</tbody>
</table>

Watanabe et al., unpublished
Rumen acidosis: more than just the rumen!

Pederzolli, unpublished
What is gut health?

- Efficient nutrient absorption
- Good types of microbes
- Good fibre digestion capability
- Good barrier function
- Regulated pH
- Optimal bacterial protein production
- Large rumen papillae
- Adequate capacity
- Balanced residence time and passage rate
What is gut health?

**Forage-based**

**Attributes**
- Active and regulated microbial community (fibre digestion)
- Nutrient absorption
- Barrier function

**Requirements**
- Consistent supply of dry matter and nutrients

**Concentrate-based**

**Attributes**
- Active and regulated microbial community (starch digestion)
- Nutrient absorption
- Barrier function

**Requirements**
- Consistent supply of dry matter and nutrients
Challenges to gastrointestinal function?

- Inherent challenges within current production settings
  - Management
    - Weaning
    - Dietary challenges
  - Environment
    - Heat stress
    - Competition
  - Physiological
    - Parturition

Low/transient low feed intake
Rapid dietary change / induction of rumen acidosis
Direct effects of ruminal acidosis

Calsamiglia et al., 2002; JDS
Low pH induces an inflammatory response

Khafipour et al., 2012: CJAS
Low pH induces an inflammatory response

Khafipour et al., 2012: CJAS
Barrier function of the rumen epithelium

Aschenbach and Gäbel, 2000; JAS
Acidification impairs absorption

Wilson et al., 2012; JAS
CONTROL

ACIDOSIS

Steele et al., 2009
CONTROL

ACIDOSIS

Steele et al, 2009
Inconsistent nutrient supply: the real challenge for gut health

- Variation in DMI and nutrient intake alters:
  - Nutrient supply for microbes
  - Growth response and antigen release
  - Nutrients available for cattle
  - Function of the rumen and whole gut
Weaning compromises total tract barrier function

- 14 newborn Holstein bull calves
- Weaned on d 42 after a 7 d step-down program vs. or not weaned
- Cr-EDTA used as an indicator of barrier function

Greater urinary Cr = reduced barrier function

Wood et al., 2015: JDS
Low feed intake for newly received feedlot cattle

<table>
<thead>
<tr>
<th>Variable</th>
<th>1st week</th>
<th>2nd week</th>
<th>3rd and 4th weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMI (% of BW)</td>
<td>0.5% to 1.5%</td>
<td>1.5% to 2.5%</td>
<td>2.5% to 3.5%</td>
</tr>
</tbody>
</table>

Hutcheson and Cole, 1986; JAS

Absorption, % of pre-feed withdrawal

Gäbel et al., 1993
Variation in nutrient supply: beef cow example

- Swathgrazing – forage allocation cycle
  - 3 d/paddock or longer

![Graph showing pH duration for different forage types](attachment:image.jpg)

Jose, Penner, McKinnon, Lardner, unpublished
Information Required

- Does the severity of short-term feed restriction affect the absorptive and barrier functions of the gastrointestinal tract?

- Does the severity of short-term feed restriction affect recovery of absorptive and barrier function?

- Can we manipulate the diet to mitigate the response?
18 cannulated Angus heifers

- 3 treatments
  - 75% of feed ad libitum
  - 50% of feed ad libitum
  - 25% of feed ad libitum

5 periods

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>% of DM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley silage</td>
<td>30</td>
</tr>
<tr>
<td>Grass-Alfalfa hay</td>
<td>30</td>
</tr>
<tr>
<td>Barley grain (rolled)</td>
<td>32</td>
</tr>
<tr>
<td>Pellet</td>
<td>8</td>
</tr>
</tbody>
</table>

Nutrient composition

- DM, %: 65.8 ± 1.9
- OM, % of DM: 92.3 ± 1.2
- CP, % of DM: 11.2 ± 0.4
- Fat, % of DM: 1.8 ± 0.0
- NDF, % of DM: 40.1 ± 0.4

Zhang et al., 2013; JAS
Feed restriction decreases the VFA (nutrients for cows) in the rumen

Treatment × period; $P < 0.001$

Zhang et al., 2013
Rumen pH increases during feed restriction

Treatment × period; $P < 0.001$

Duration (pH < 5.5), min/d

Period; $P < 0.001$

Zhang et al., 2013
Nutrient absorption is reduced with feed restriction

**Zhang et al., 2013**

Period: $P = 0.091$

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Total SCFA, mmol/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>75%</td>
<td>650</td>
</tr>
<tr>
<td>50%</td>
<td>550</td>
</tr>
<tr>
<td>25%</td>
<td>450</td>
</tr>
</tbody>
</table>

Treatment: $P = 0.080$
Barrier function of the gut is reduced with feed restriction

Treatment × period; $P < 0.001$

Zhang et al., 2013
Feed restriction impacts cattle when they return to full feed conditions

Treatment × period; $P < 0.001$

Zhang et al., 2013
Ad libitum feeding after feed restriction induces rumen acidosis

Zhang et al., 2013; JAS
Absorption capability did not recover until about 3 wk after feed restriction.
Management strategies to improve gut health

- Consistent feed supply that meets nutrient requirements
  - Good husbandry, bunk management, grain processing
- Feed additives that help to stabilize rumen fermentation
  - Ionophores, yeast, probiotics, essential oils, etc.
- Can we predict the low feed intake event?
  - Recovery diets?
Can We Mitigate the Response by Changing the Forage-to-Concentrate Ratio?

- Animals and Experimental Design
- 20 cannulated Angus heifers
  - 4 treatments
    - High forage/High forage
    - High forage/Moderate forage
    - Moderate forage/High forage
    - Moderate forage/Moderate forage

Albornoz et al., 2013
Role of forage in recovery after low feed intake

<table>
<thead>
<tr>
<th>Ingredient, % of DM</th>
<th>Treatment¹</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HF</td>
<td>MF</td>
<td></td>
</tr>
<tr>
<td>Grass hay</td>
<td>46</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Barley silage</td>
<td>46</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Barley grain</td>
<td>0</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>Pellet²</td>
<td>8</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chemical composition,³ g/kg ± SD</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>DM</td>
<td>584 ± 69.7</td>
<td>557 ± 47.3</td>
</tr>
<tr>
<td>OM</td>
<td>907 ± 2.3</td>
<td>925 ± 1.9</td>
</tr>
<tr>
<td>CP</td>
<td>107 ± 5.7</td>
<td>111 ± 5.4</td>
</tr>
<tr>
<td>Crude fat</td>
<td>21 ± 0.4</td>
<td>19 ± 0.7</td>
</tr>
<tr>
<td>NDF</td>
<td>527 ± 4.6</td>
<td>405 ± 1.4</td>
</tr>
<tr>
<td>ADF</td>
<td>291 ± 5.4</td>
<td>209 ± 4.5</td>
</tr>
<tr>
<td>NEm,⁴ MJ/kg</td>
<td>4.61</td>
<td>6.09</td>
</tr>
<tr>
<td>NEg,⁴ MJ/kg</td>
<td>2.03</td>
<td>2.21</td>
</tr>
</tbody>
</table>

Albornoz et al., 2013; JAS
Low feed intake decreases SCFA absorption

Albornoz et al., 2013; JAS
Feeding a high forage diet improves recovery

DMI, kg/d

Week 1 Week 2 Week 3

Duration pH < 5.5, min/d

Week 1 Week 2 Week 3

Treat x period, $P = 0.033$

Treat x period, $P < 0.001$

Albornoz et al., 2013; JAS
Nutritional strategies to accelerate recovery of the gastrointestinal tract (GIT)

- Several nutrients may help promote GIT function
  - Butyrate  
    - Butyrate  Gorka et al., 2013; Kawalski et al., 2015
  - Betaine
    - Coccidia infection  Kettunen et al. 2001; Fetterer et al. 2003
  - Antioxidants
    - Superoxide dismutase benefits GIT in mice  Vouldoukis et al. 2004
    - May counteract hypoxic conditions  Dengler et al., 2015
Use of a compound feed additive to accelerate recovery of the GIT

- n = 32
- Fed ‘High’
- 3 d low feed intake at 50%

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</thead>
<tbody>
<tr>
<td>Barley silage</td>
<td>High: 9</td>
</tr>
<tr>
<td>Barley grain</td>
<td>High: 79</td>
</tr>
<tr>
<td>Min/vit</td>
<td>High: 12.5</td>
</tr>
<tr>
<td>RP betaine</td>
<td>High: 0.7</td>
</tr>
<tr>
<td>Antioxidant</td>
<td></td>
</tr>
<tr>
<td>Butyrate</td>
<td></td>
</tr>
</tbody>
</table>

Penner et al., unpublished
Use of a compound feed additive to accelerate recovery of the GIT

Baseline LFI Recovery

CON = no LFI

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<td>RP betaine</td>
<td></td>
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<td>Antioxidant</td>
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</tr>
</tbody>
</table>

Penner et al., unpublished
Increasing the F:C ratio and use of a compound supplement stabilized DMI

Only STORM+ recovered to baseline DMI after low feed intake

Penner et al., unpublished
Increasing the F:C ratio and use of a compound supplement stabilized pH

Treatment x period, $P = 0.022$

Penner et al., unpublished
Increasing the F:C ratio and use of a compound supplement improved absorption $P = 0.011$

**Flux rate, µmol/(cm² × h)**

- **CON**
- **LFI**
- **STORM**
- **STORM+**

$P = 0.089$

Penner et al., unpublished
Take-home messages

- A consistent supply of DM and nutrients are required to maintain gut health
- Production responses have not been well characterized but can be extrapolated
- Management strategies to minimize variation in intake may yield greatest rewards
- Recovery following a challenge takes time but can be accelerated
Thank you ALMA
Alberta Livestock and Meat Agency Ltd.

Saskatchewan Ministry of Agriculture

Natural Sciences and Engineering Research Council of Canada

Conseil de recherches en sciences naturelles et en génie du Canada