Starch digestibility in dairy cows – how do we handle starch in ration evaluation systems?

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Ruminant starch digestion

- Glucose: 97% of energy
- VFA: 62% of energy
- VFA Microbial protein: 80% of energy

RUMEN

SMALL INTESTINE

HIND GUT
Outline

• Recent DK studies on starch digestibility
• How to handle starch in feed evaluation models
• Suggestion for in vivo approach
• Major future challenges regarding starch
Starch digestibility in Dairy cows – variable!

- Faba bean, toasted 150°C, rolled
- Smooth pea, toasted 140°C, ground
- Smooth pea, xylose, cracked
- Smooth pea, ground (exp. 2)
- Wrinkled pea, rolled
- Wrinkled pea, toasted 140°C, rolled
- Maize, ground
- Faba bean, toasted 140°C, ground
- Faba bean, rolled
- Faba bean, toasted 120°C, rolled
- Faba bean, ground
- Barley, xylose, cracked
- Wheat, xylose, cracked
- Smooth pea, ground (exp. 1)
- Oats, rolled
- Wheat, ground
- Barley, ground
- Barley, gelatinised, rolled
- Barley, gelatinised, ground
- Barley, cracked
- Ear maize, pelleted
- Wheat, rolled
- Barley, rolled
- Wheat, gelatinised, rolled
- Wheat, cracked

Digested starch, g/kg starch intake
Maize silage – effect of maturity/DM

<table>
<thead>
<tr>
<th>Intake, flow and digestibility of starch in different sections of digestive tract</th>
<th>Treatment(^d)</th>
<th>RMSE</th>
<th>(P) (linear)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MS260</td>
<td>MS350</td>
<td>MS400</td>
</tr>
<tr>
<td>Intake (kg/day)</td>
<td>2.10</td>
<td>3.56</td>
<td>3.72</td>
</tr>
<tr>
<td>Flow (kg/day)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duodenal</td>
<td>0.13</td>
<td>0.31</td>
<td>0.29</td>
</tr>
<tr>
<td>Duodenal corr.(^a)</td>
<td>0.15</td>
<td>0.34</td>
<td>0.36</td>
</tr>
<tr>
<td>Ileal</td>
<td>0.02</td>
<td>0.08</td>
<td>0.06</td>
</tr>
<tr>
<td>Faecal</td>
<td>0.001</td>
<td>0.05</td>
<td>0.08</td>
</tr>
<tr>
<td>Digestibility</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foreestomach(^a,b)</td>
<td>0.93</td>
<td>0.91</td>
<td>0.91</td>
</tr>
<tr>
<td>Small intestine(^a,c)</td>
<td>0.91</td>
<td>0.78</td>
<td>0.85</td>
</tr>
<tr>
<td>Total tract(^b)</td>
<td>1.00</td>
<td>0.99</td>
<td>0.98</td>
</tr>
</tbody>
</table>
## Corn cob silage – Dairy cows

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Barley</th>
<th>Corn cob silage</th>
<th>NaOH wheat</th>
<th>SEM</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter intake (kg/day)</td>
<td>19.0</td>
<td>18.2</td>
<td>19.7</td>
<td>0.4</td>
<td>0.2</td>
</tr>
<tr>
<td>DM</td>
<td>71.0</td>
<td>68.1</td>
<td>73.8</td>
<td>2.0</td>
<td>0.3</td>
</tr>
<tr>
<td>OM</td>
<td>72.7</td>
<td>70.1</td>
<td>76.6</td>
<td>2.1</td>
<td>0.3</td>
</tr>
<tr>
<td>NDF</td>
<td>54.6</td>
<td>55.2</td>
<td>62.6</td>
<td>4.0</td>
<td>0.4</td>
</tr>
<tr>
<td>Starch</td>
<td>98.3</td>
<td>99.3</td>
<td>99.2</td>
<td>0.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Protein</td>
<td>66.1</td>
<td>64.3</td>
<td>68.2</td>
<td>2.4</td>
<td>0.6</td>
</tr>
</tbody>
</table>

Hymøller et al. 2013, submitted
Rye – upcoming in Denmark for feeding, and not just for rye bread

- Rolled rye: 881 g/kg starch intake
- NaoH rye: 787 g/kg starch intake

Digestion in different parts of the digestive system:
- Rumen: 92 g/kg starch intake
- Small intestine: 922 g/kg starch intake
- Hind gut: 131 g/kg starch intake
Conclusion - Starch digestibility in dairy cows

- Starch digestibility variable, also in Danish starch sources
- Digestibility and rumen degradability of ensiled starch is high
Outline

• Recent DK studies on starch digestibility
• How to handle starch in feed evaluation models
• Suggestion for in vivo approach
• Major future challenge regarding starch
In vitro – in situ vs in vivo - starch

Conclusion

• Weak correlations between in situ and in vitro kd
• Effective degradability - OK correlations for both methods
• IS $k_d$ values unrealistic, however ESD values correlated well

Weisbjerg et al. 2011
Mobile bag assessment of in vivo starch digestibility

Conclusion
• Weak correlations between *in vivo* and mobile bag digestibilities

Ghoorchi et al. 2012, Animal, 7, 265-271
Conclusion – estimation of starch digestibility

• No obvious lab method for estimation of starch digestibility
• Probably because both physical form, processing (heat, ensiling, etc.) and origin (protein matrix?) influence starch digestibility – therefore e.g. standardised milling hamper assessment
• Then, at present, in vivo approach seems most appropriate, as it seems that only the animals can give the right answer!
Outline

• Recent DK studies on starch digestibility
• How to handle starch in feed evaluation models
• Suggestion for in vivo approach
• Major future challenge regarding starch
Literature data – dairy cows

62 publications
Observations as treatment means
Selection criteria:
• Lactating dairy cows
• At least total tract starch digestibility, preferentially rumen, small intestinal and hind gut

<table>
<thead>
<tr>
<th>Starch digestibility</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total tract</td>
<td>279</td>
</tr>
<tr>
<td>Rumen</td>
<td>173</td>
</tr>
<tr>
<td>Small intestine</td>
<td>54</td>
</tr>
<tr>
<td>Hind gut</td>
<td>57</td>
</tr>
</tbody>
</table>
Database included

- Nutrient intakes
- Starch flow (digestibilities)
- Name of main starch sources (2 main concentrate and 2 main forage sources, if appropriate)
- Proportion of total starch intake coming from these 4 starch sources
- In total 21 starch sources
Challenge in using in vivo data for lactating cow rations:

• Most examined rations contain more than one starch source!
Data analysis

Regression and multiple regression analysis

$Y = \text{starch digestibility, total or in different digestive compartments}$

- $Y = \text{starch intake/escape} + \text{proportion of starch source}_{1-21}$
- $Y = \text{starch intake/escape}$
- $Y = \text{proportion of starch source}_{1-21}$
Main results – regression analyses

Rumen and total digestibility →
  info on source (name) necessary

Small intestinal digestibility →
  positively correlated to rumen degradability – source (name) still important

Hind gut digestibility →
  source (name) not important - positively correlated to rumen degradability [opposite to hypothesis!!]
Digestibilities for individual starch sources
## Digestibilities - estimated using GLM –
obs. dig = source digestibility x source prop. of ration total starch

<table>
<thead>
<tr>
<th>Starch source</th>
<th>Total tract</th>
<th>Rumen</th>
<th>Small intestine</th>
<th>Hind gut</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheat Starch</td>
<td>1016</td>
<td>1067</td>
<td>739</td>
<td>704</td>
</tr>
<tr>
<td>Corn starch</td>
<td>999</td>
<td>863</td>
<td>669</td>
<td>753</td>
</tr>
<tr>
<td>Wheat</td>
<td>999</td>
<td>915</td>
<td>679</td>
<td>622</td>
</tr>
<tr>
<td>Oat</td>
<td>989</td>
<td>870</td>
<td>703</td>
<td>696</td>
</tr>
<tr>
<td>Faba beans</td>
<td>961</td>
<td>799</td>
<td>360</td>
<td>664</td>
</tr>
<tr>
<td>Barley</td>
<td>952</td>
<td>860</td>
<td>719</td>
<td>545</td>
</tr>
<tr>
<td>Corn silage (CS)</td>
<td>931</td>
<td>629</td>
<td>840</td>
<td>624</td>
</tr>
<tr>
<td>CS high¹</td>
<td>962</td>
<td>910</td>
<td>820</td>
<td>655</td>
</tr>
<tr>
<td>Wheat NaOH</td>
<td>929</td>
<td>648</td>
<td>710</td>
<td>54</td>
</tr>
<tr>
<td>Wrinkled pea</td>
<td>922</td>
<td>740</td>
<td>225</td>
<td>616</td>
</tr>
<tr>
<td>Corn</td>
<td>913</td>
<td>544</td>
<td>509</td>
<td>458</td>
</tr>
<tr>
<td>Sorghum</td>
<td>905</td>
<td>619</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Smooth pea</td>
<td>899</td>
<td>780</td>
<td>472</td>
<td>463</td>
</tr>
<tr>
<td>Barley NaOH</td>
<td>839</td>
<td>670</td>
<td>203</td>
<td>389</td>
</tr>
</tbody>
</table>

Green = highest, blue=high, purple=low, red =lowest

1 → corn silage > 60% of ration starch
How can this be used to model starch digestion in practical feed evaluation models?

Rumen: $k_d$ calculated from in vivo rumen digestibility, and tabulated

Small intestine: function of rumen digestibility (if we forget about starch source, problematic with legumes) or use estimates for digestibility of individual sources

Hind gut: function of rumen digestibility
NorFor update - changed starch model
A new version of the NorFor model was released on June 4, called FRC 1.76. The new update includes a modified calculation of starch digestibility and a recommendation for individual amino acids. We will come back with more information later on amino acids and focus on starch in this newsletter.

http://norfor.info/

However only partly introduced at present, post rumen digestion in NorFor as regressions on rumen escape
Outline

• Recent DK studies on starch digestibility
• How to handle starch in ration evaluation models
• Suggestion for in vivo approach
• Major future challenge regarding starch
Major remaining question

- How does starch pass out of the rumen

- How to assess starch digestibility in samples where no in vivo data are available (‘new’ starch sources, processed starch, commercial concentrates)?
Starch passage!

(A) Flow of starch (g/h) vs. Time after feeding (h) for untreated barley and expanded barley.

(B) Flow of starch (g/h) vs. Time after feeding (h) for untreated maize and expanded maize.

Innovative and practical management approaches to reduce nitrogen excretion by ruminants

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It does not necessarily reflect its view and in no way anticipates the Commission’s future policy in this area.