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Molecular weight changes of arabinoxylans incurred by the digestion processes in the upper gastrointestinal tract of pigs

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Introduction

In Humans, the health promoting effects are brought about by intact cell walls (insoluble DF) and luminal viscosity (soluble DF) which may interfere with the digestion and absorption process at all sites of the gastrointestinal (GI) tract. In diets for piglets, however, soluble DF (e.g. pectins, guar gum, β-glucan and arabinoxylans (AX)) has been linked to a higher risk of developing post-weaning enteric disorders.

From an earlier study, we know that oat β-glucan is depolymerised and degraded to a large extent during upper GI tract passage of pigs. Our knowledge about the changes in molecular weight (MW) of AX, the main DF polysaccharide of wheat and rye, however, is limited.

In the present study, we therefore investigated the MW of AX in wheat and rye based diets and in the soluble phase of digesta after passage of the upper GI tract.

Materials and methods

Animals and Diets

Growing pigs: n=20; initial BW: 64.9 ± 1.2 kg.
-4 dietary groups (3 blocks of 2, 2 and 1 pig)
- Fitted with T-cannula,
- Placed in individual cages,
- Fed three times daily (8.00, 13.00 and 18.00 hours).

Diet: standard white wheat soft flour and wheat refined fibre (WFL), whole wheat grain (WWG), wheat aleurone flour (WAF) and rye aleurone flour (RAF) made as breads.

Methods and Measurements

Ileal digesta: collected for three periods (8.00-13.00 (C1), 13.00-15.30 (C2) and 15.30-18.00 hours (C3)) after feeding.
-A part was immediately separated by centrifugation (10.000 x g; 20 min) into supernatant and solid phase. The supernatant was frozen until further analysis.

Analysis: molecular weight of ileal supernatants and dietary water extracts (WE) was determined after size exclusion chromatography separation and refractive index detection.
- Viscosity measurements were done on the same extracts.

Statistics: All data were analysed by the Mixed procedure (SAS) to test the diet, the collection and their interaction effect with blocks of 5 pigs. The correlation between the log transformed [c×MWw] and log viscosity was calculated as Pearson’s product-moment correlation coefficient by using Proc corr.

Acknowledgement: to the European Union for financial support (“HealthGrain”, contract number FP6-514008).

Results

1)- Average MWw of AX:
- 1.8 – 3.8 × 10⁵ in diets,
- When compared with the MWw of water extracts, it not modified after feeding the wheat based diets, but reduced by ~ 20 % after feeding the RAF diet (P diet=0.009; P interaction=0.007).

2)- Concentration of soluble AX:
- No effect of time after feeding the wheat based diets,
- [AX]s was higher during the afternoon collection (C2) when feeding the RAF diet.

3)- Viscosity of ileal digesta:
- No effect of time after feeding (P=0.16),
- Higher after feeding the RAF diet than the wheat based diets, (P<0.001).

Conclusion

The degradation of AX from wheat and rye after passing the upper GI tract is much lower than β-glucan from oats. Although the AX in the RAF diet was reduced more than the case with AX from the wheat based diets, the higher concentration and MW of the AX from rye leads to a higher viscosity which may impact the digestion processes in the upper GI tract.
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Introduction

Consumption of a diet rich in dietary fibre (DF) has been suggested as a strategy to reduce the risk of development of obesity and associated diseases like cardiovascular diseases and type-2 diabetes. The health promoting effects are brought about by intact cell walls (insoluble DF) and luminal viscosity (soluble DF) which may interfere with the digestion and absorption process at all sites of the gastrointestinal (GI) tract. In diets for piglets, however, soluble DF has been linked to a higher risk of developing post-weaning enteric disorders.

Soluble DF polysaccharides that have these properties are pectin, guar gum, β-glucan and arabinoxylans (AX).

From an earlier study we know that oat β-glucan is depolymerised and degraded to a large extent during passage of stomach and small intestine of pigs. Our knowledge about the changes in molecular weight (MW) of AX, the main DF polysaccharide of wheat and rye, however, is limited. In the present study, we therefore investigated the MW of AX in wheat and rye based diets and associated diseases like cardiovascular diseases and type-2 diabetes. The health promoting effects are brought about by intact cell walls (insoluble DF) and luminal viscosity (soluble DF) which may interfere with the digestion and absorption process at all sites of the gastrointestinal (GI) tract.

Materials and methods

Animals and Diets

Growing pigs: n=20; initial BW: 64.9 ± 1.2 kg.
- 4 dietary groups (3 blocks of 2, 2 and 1 pig)
  - Fitted with T-cannula,
  - Placed in individual cages,
  - Fed three times daily (8.00, 13.00 and 18.00 hours).

Diets: standard white wheat soft flour and wheat refined fibre (WFL), whole wheat grain (WWG), wheat aleurone flour (WAF) and rye aleurone flour (RAF) made as breads.

Methods and measurements

Ileal digesta: collected for three periods (8.00-13.00 (C1), 13.00-15.30 (C2) and 15.30-18.00 hours (C3)) after feeding on days 15 and 17 after surgery,
- Pooled across collections from the same period for the two days within each pig,
- A part was frozen until further analysis and a second part was immediately centrifuged (10.000g, 20 min) into supernatant and solid phase. The supernatant was frozen until further analysis.

Analysis: molecular weight of ileal supernatants and dietary water extracts was determined after exclusion chromatography separation and refractive index detection. Viscosity measurements were done on the same extracts.

Statistics: AX concentration, viscosity and MW data were analysed by the Mixed procedure (SAS) to test the diet, the collection and their interaction effect with blocks of 5 piglets. The correlation between the log transformed [c×MWw] and log viscosity was calculated as Pearson’s product-moment correlation coefficient by using Proc corr.

Results and discussion

1. MW of soluble ileal digesta

2. Concentration of soluble AX

3- Viscosity of ileal digesta

Figure 1. HPSEC-RI profiles of supernatants from water extracts of WAF or RAF diet and ileal digesta from 3 collections after WAF or RAF feeding (C1: 8.00-13.00, (C2): 13.00-15.30, (C3): 15.30-18.00).

- Any modification on profiles after WAF feeding
- Shift in retention time of the population of the highest MW toward higher retention times after RAF feeding, indicating a degradation of this population a shift in retention time of the population of the highest MW toward higher retention times indicating a degradation of this population.

Figure 2. Weight average MW (MWw) of AX (×105) (1), concentration of soluble AX (2) in ileal digesta collected in three successive collection (C1, C2, C3) after feeding the four experimental diets. Pooled viscosity (3) of soluble phase after feeding the four experimental diets.

- 1) Average MWw of AX:
  - 1.8 – 3.8 × 106 in diets (not shown),
  - not modified after feeding the wheat based diets, but reduced by ~ 20 % after feeding the RAF diet when compared with the MWw of water extracts (P diet=0.009; P interaction=0.007).

- 2) Concentration of soluble AX:
  - No effect of time after feeding the wheat based diets,
  - Higher during the afternoon collection (C2) after feeding the RAF diet.

- 3) Viscosity of ileal digesta:
  - No effect of time after feeding (P=0.16),
  - Higher after feeding the RAF diet than the wheat based diets, (P<0.001).

Figure 3. Relationship between the log of the multiple between the concentration of soluble AX in ileal digesta and the weight average MWw and the log viscosity of the ileal digesta.

- Linear relationship indicating that the variation in ileal viscosity was due to the presence of soluble AX in ileal digesta of variable MW.

Conclusion

The degradation of AX from wheat and rye after passing the upper GI tract is much lower than of β-glucan from oats. Although the AX in the RAF diet was reduced more than is the case with AX from the wheat based diets, the higher concentration and MW of the AX from rye leads to a higher viscosity which may impact the digestion processes in the upper GI tract.
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Materials and methods

Animals and Diets

Growing pigs: n=20; initial BW: 64.9 ± 1.2 kg,
- Three successive blocks of two, two and one pigs per block, 4 groups,
- Fitted with T-cannula,
- Placed in individual cages,
- Fed three times daily (8.00, 13.00 and 18.00 hours).
Diet: standard white wheat soft flour and wheat refined fibre (WFL), whole wheat grain (WWG), wheat alleurone flour (WAF) and rye alleurone flour (RAF) made as breads.

Methods and measurements

Ileal digesta: collected for three successive periods (8.00-13.00 (C1), 13.00-15.30 (C2) and 15.30-18.00 hours (C3)) after feeding on days 15 and 17 after surgery,
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Statistics: AX concentration, viscosity and MW data were analysed by the Mixed procedure (SAS) to test the diet, the collection and their interaction effect with blocks of 5 piglets. The correlation between the log transformed [C x MW] and log viscosity was calculated as Pearson’s product-moment correlation coefficient by using Proc corr.

Results and discussion

The distribution of AX concentration in ileal digesta collected in three successive collection (C1, C2, C3) after feeding the four experimental diets.

Average MW of AX:
- 1.8 – 3.8 x 10³ in diets (not shown),
- not modified after feeding the wheat based diets, but reduced by ~ 20 % after feeding the RAF diet when compared with the MW of water extracts (P<0.005; P interaction=0.007).

Concentration of soluble AX:
- No effect of time after feeding the wheat based diets,
- Higher during the afternoon collection (C2) after feeding the RAF diet.

Viscosity of ileal digesta:
- No effect of time after feeding (P<0.16),
- Higher after feeding the RAF diet than the wheat based diets, (P<0.001).

The degradation of AX from wheat and rye after passing the upper GI tract is much lower than of β-glucan from oats. Although the AX in the RAF diet was reduced more than is the case with AX from the wheat based diets, the higher concentration and MW of the AX from rye leads to a higher viscosity which may impact the digestion processes in the upper GI tract.

Conclusion

Acknowledgement: to the European Union for financial support (“HealthGrain”, contract number FP6-514008).

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Table 1. Concentration of soluble AX, viscosity of soluble phase, weight average MW (MWw) of AX ($\times 10^5$) and MW of three main peaks of AX in ileal digesta collected in three successive intervals after feeding the four experimental diets.

<table>
<thead>
<tr>
<th>Collection periods</th>
<th>WFL</th>
<th>WWG</th>
<th>WAF</th>
<th>RAF</th>
<th>SEM</th>
<th>Diet</th>
<th>Diet x Collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soluble AX, g/kg of digesta DM</td>
<td>C1</td>
<td>C2</td>
<td>C3</td>
<td>C1</td>
<td>C2</td>
<td>C3</td>
<td>C1</td>
</tr>
<tr>
<td>Viscosity</td>
<td>1.84</td>
<td>1.41</td>
<td>1.96</td>
<td>1.51</td>
<td>1.08</td>
<td>1.34</td>
<td>7.4</td>
</tr>
<tr>
<td>MWw, (\times 10^5)</td>
<td>46.7</td>
<td>54.6</td>
<td>30.8</td>
<td>46.6</td>
<td>57.9</td>
<td>54.1</td>
<td>30.5</td>
</tr>
</tbody>
</table>