Nutritional Value of Hybrid Rye for Pigs

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UNIVERSITY OF ILLINOIS
Outline

BACKGROUND
DIGESTIBLE NUTRIENTS
PIG PERFORMANCE

STARCH
FIBER
AMINO ACIDS
PHOSPHORUS
Hybrid Rye
Objective of swine nutrition

“Provide each nutrient in both quantity and form that will precisely meet the pig’s requirements for growth, reproduction, milk production, and if necessary, maintenance, at the least possible cost.”

-Dr. Robert Easter
FEED INGESTION

ILEAL OUTPUT = ileal digestibility

FECAL OUTPUT = total tract digestibility
Procedure for measuring ileal digestibility

Used for:
AMINO ACIDS
STARCH
Procedure for measuring total tract digestibility

Used for:
- ENERGY
- MINERALS
- FIBER

1 day

ADAPTATION

5

COLLECTION

10
Apparent and standardized ileal digestibility of AA and starch in hybrid rye, barley, wheat, and corn fed to growing pigs

Molly L. McGhee and Hans. H. Stein

Department of Animal Sciences, University of Illinois, Urbana, IL 61801

ABSTRACT: An experiment was conducted to determine the apparent ileal digestibility (AID) of AA and starch and the standardized ileal digestibility (SID) of AA in three varieties of hybrid rye and in one source of barley, wheat, and corn. Seven growing barrows (initial BW = 26.1 ± 2.4 kg) were randomly allotted to a 7 × 7 Latin square design with seven periods and seven experimental diets. Six diets included one of the grains as the sole source of AA, and an N-free diet was used to determine basal endogenous losses of CP and AA. In each period, ileal digesta were collected for 8 h on days 6 and 7 following a 5-d adaptation period. At the conclusion of the experiment, all ingredients, diets, and ileal digesta samples were analyzed for starch, CP, and AA. The AID of starch was greater (P < 0.05) in wheat and corn than in barley or hybrid rye, but all grains had AID values for starch that were above 95%. Wheat and barley contained more CP and indispensable AA than hybrid rye, but hybrid rye contained more indispensable AA compared with corn. The SID of CP and all indispensable AA was greater (P < 0.05) in barley, wheat, and corn than in the three varieties of rye. However, because of the greater concentration of AA in hybrid rye than in corn, the quantities of standardized ileal digestible CP and AA were not different between corn and hybrid rye. In conclusion, hybrid rye has greater concentrations of most AA than corn, but the digestibility of AA in rye is less than in other cereal grains. It is likely that the reason for the reduced SID of AA in rye is that rye contains more fructans and soluble dietary fiber than other cereal grains, which may increase viscosity and reduce the efficiency of endogenous peptidases.

Key words: AA digestibility, cereal grains, hybrid rye, pigs, starch digestibility

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doi: 10.1093/jas/sky206
SID = 64%

0.41% Lysine
0.26% SID Lysine
Digestible Lysine (SID)

<table>
<thead>
<tr>
<th></th>
<th>Undigested</th>
<th>Digested</th>
<th>Total [Lys] in grain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hybrid Rye</td>
<td>62% b</td>
<td>77% a</td>
<td>77% a</td>
</tr>
<tr>
<td>DH Barley</td>
<td>77% a</td>
<td>79% a</td>
<td>79% a</td>
</tr>
<tr>
<td>Wheat</td>
<td>79% a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>78% a</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$P < 0.05$
Digestible Methionine (SID)

<table>
<thead>
<tr>
<th>Grain</th>
<th>Methionine, %</th>
<th>Undigested</th>
<th>Digested</th>
<th>Total [Met] in grain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hybrid Rye</td>
<td>76% c</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DH Barley</td>
<td>86% b</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td>89% ab</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>91% a</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

P < 0.05
Digestible Threonine (SID)

<table>
<thead>
<tr>
<th></th>
<th>Undigested</th>
<th>Digested</th>
<th>Total [Thr] in grain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hybrid Rye</td>
<td>64% b</td>
<td>27% b</td>
<td>91% b</td>
</tr>
<tr>
<td>DH Barley</td>
<td>24% a</td>
<td>57% a</td>
<td>81% a</td>
</tr>
<tr>
<td>Wheat</td>
<td>8% a</td>
<td>72% a</td>
<td>80% a</td>
</tr>
<tr>
<td>Corn</td>
<td>18% a</td>
<td>64% a</td>
<td>82% a</td>
</tr>
</tbody>
</table>

P < 0.05
Digestible Tryptophan (SID)

<table>
<thead>
<tr>
<th>Grain Type</th>
<th>Tryptophan, %</th>
<th>P &lt; 0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hybrid Rye</td>
<td>72% b</td>
<td></td>
</tr>
<tr>
<td>DH Barley</td>
<td>88% a</td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td>90% a</td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>89% a</td>
<td></td>
</tr>
</tbody>
</table>

P < 0.05

Digestion:
- Undigested
- Digested
- Total [Trp] in grain
Exp. 1 Conclusions

**AA digestibility:** Hybrid rye < Other grains

Antinutritive factors (insoluble fiber), viscosity

**Quantities of digestible AA:** Hybrid rye ≈ corn

Similar diet formulations for corn & rye
Effects of microbial phytase on standardized total tract digestibility of phosphorus in hybrid rye, barley, wheat, corn, and sorghum fed to growing pigs

Molly L. McGhee and Hans H. Stein

Department of Animal Sciences, University of Illinois, Urbana, IL 61801

ABSTRACT: An experiment was conducted to determine the apparent total tract digestibility (ATTD) and the standardized total tract digestibility (STTD) of P in three varieties of hybrid rye and in one source of barley, wheat, corn, and sorghum. The STTD of P in each cereal grain was determined both without and with addition of microbial phytase. In total, 112 growing barrows (13.7 ± 1.3 kg initial BW) were allotted to a randomized complete block design with four blocks of 28 pigs. Pigs were randomly allotted to 14 diets with two replicate pigs per diet in each block, resulting in a total of eight replicate pigs per diet for the four blocks. Each diet contained one of the cereal grains as the sole source of P. There were two diets with each cereal grain with one diet containing no microbial phytase and the other diet containing 1,000 units of microbial phytase per kilogram of diet. In each period, fecal output was collected for 5 d following a 5-d adaptation period according to the marker-to-marker procedure. Among the diets that did not include microbial phytase, one hybrid of rye had greater ($P < 0.05$) STTD of P than wheat, corn, and sorghum, which is likely a result of the greater intrinsic phytase activity in rye than in the other cereal grains. Without microbial phytase, there was no difference in the STTD of P in the three hybrids of rye and barley. Among the diets containing microbial phytase, there was no difference in STTD of P among the three hybrids of rye, barley, and corn. The STTD of P in the three hybrids of rye with microbial phytase was 61.9%, 70.8%, and 63.0%, respectively. Overall, microbial phytase improved ($P < 0.05$) the STTD of P in all cereal grains, although the magnitude of the increase in STTD of P differed among the grains.

Key words: calcium, cereal grains, digestibility, hybrid rye, phosphorus, pigs

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doi: 10.1093/tas/ttx088
STTD = 49%

WHAT IF WE ADD PHYTASE?

0.29% Phosphorus
0.14% STTD P
STTD = 49% 63%

0.29% Phosphorus

0.18% STTD P

WHAT IF WE ADD PHYTASE?
Digestible Phosphorus (STTD)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rye</td>
<td>0.15</td>
<td>0.34</td>
<td>0.49</td>
</tr>
<tr>
<td>Barley</td>
<td>0.13</td>
<td>0.23</td>
<td>0.36</td>
</tr>
<tr>
<td>Wheat</td>
<td>0.16</td>
<td>0.32</td>
<td>0.48</td>
</tr>
<tr>
<td>Corn</td>
<td>0.15</td>
<td>0.30</td>
<td>0.45</td>
</tr>
<tr>
<td>Sorghum</td>
<td>0.12</td>
<td>0.34</td>
<td>0.46</td>
</tr>
</tbody>
</table>
Digestible Phosphorus (STTD)

<table>
<thead>
<tr>
<th>Undigested</th>
<th>Digested</th>
<th>Total [P] in grain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rye -</td>
<td>49%</td>
<td>68%</td>
</tr>
<tr>
<td>Rye +</td>
<td>63%</td>
<td>58%</td>
</tr>
<tr>
<td>Barley -</td>
<td>45%</td>
<td>37%</td>
</tr>
<tr>
<td>Barley +</td>
<td>68%</td>
<td>25%</td>
</tr>
<tr>
<td>Wheat -</td>
<td>37%</td>
<td>17%</td>
</tr>
<tr>
<td>Wheat +</td>
<td>58%</td>
<td>63%</td>
</tr>
<tr>
<td>Corn -</td>
<td>49%</td>
<td>68%</td>
</tr>
<tr>
<td>Corn +</td>
<td>63%</td>
<td>54%</td>
</tr>
<tr>
<td>Sorghum -</td>
<td>49%</td>
<td>68%</td>
</tr>
<tr>
<td>Sorghum +</td>
<td>63%</td>
<td>54%</td>
</tr>
</tbody>
</table>

Digestible Phosphorus

- Rye: 49% undigested, 68% digested, total 68%
- Barley: 45% undigested, 68% digested, total 68%
- Wheat: 37% undigested, 58% digested, total 58%
- Corn: 25% undigested, 63% digested, total 63%
- Sorghum: 17% undigested, 54% digested, total 54%
Intrinsic phytase

<table>
<thead>
<tr>
<th>Plant</th>
<th>Phytase Units (FTU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hybrid 1</td>
<td>3,000</td>
</tr>
<tr>
<td>Hybrid 2</td>
<td>3,200</td>
</tr>
<tr>
<td>Hybrid 3</td>
<td>2,300</td>
</tr>
<tr>
<td>Barley</td>
<td>490</td>
</tr>
<tr>
<td>Wheat</td>
<td>580</td>
</tr>
<tr>
<td>Corn</td>
<td>50</td>
</tr>
<tr>
<td>Sorghum</td>
<td>80</td>
</tr>
</tbody>
</table>
Exp. 2 Conclusions

Hybrid rye contains large amounts of intrinsic phytase. Therefore, P digestibility is relatively high to begin with.

Microbial phytase increased P digestibility in all grains. In rye, the increase was significant, but less pronounced.

Conc. of digestible P in hybrid rye greater than in other grains

Less inorganic P needed in diets, less P excreted in feces
EXP. 3
Carbohydrate and Energy Digestibility
3,800 kcal/kg
56% starch
18% dietary fiber

ATTD
AID

Metabolizable energy
<table>
<thead>
<tr>
<th>Grain</th>
<th>Undigested</th>
<th>Digested</th>
<th>Total [Starch] in grain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rye 1</td>
<td>91% b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rye 2</td>
<td>96% ab</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barley</td>
<td>94% ab</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td>98% a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>95% ab</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sorghum</td>
<td>96% ab</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*p < 0.05*
Total dietary fiber (ATTD)

<table>
<thead>
<tr>
<th>Grain</th>
<th>Undigested</th>
<th>Digested</th>
<th>Total (TDF) in grain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rye</td>
<td>68%</td>
<td></td>
<td>68%</td>
</tr>
<tr>
<td>Barley</td>
<td>56%</td>
<td></td>
<td>56%</td>
</tr>
<tr>
<td>Wheat</td>
<td>58%</td>
<td></td>
<td>58%</td>
</tr>
<tr>
<td>Corn</td>
<td>58%</td>
<td></td>
<td>58%</td>
</tr>
<tr>
<td>Sorghum</td>
<td>58%</td>
<td></td>
<td>58%</td>
</tr>
</tbody>
</table>

$P < 0.05$
Metabolizable energy, kcal/kg DMB

<table>
<thead>
<tr>
<th>Grain</th>
<th>kcal/kg (DMB)</th>
<th>P&lt; 0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rye</td>
<td>c</td>
<td></td>
</tr>
<tr>
<td>Barley</td>
<td>d</td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td>ab</td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>a</td>
<td></td>
</tr>
<tr>
<td>Sorghum</td>
<td>bc</td>
<td></td>
</tr>
</tbody>
</table>
Exp. 3 Conclusions

Starch digestibility >90% in all cereal grains

Rye digestibility may differ among sources

Fermentation of rye fiber is more efficient than other grains

Contributes energy to pig via SCFA, may improve gut health!

Metabolizable energy in hybrid rye ≅ sorghum > barley
(Less than corn and wheat)
EXP. 4

Sow performance

OCTOBER 2018 – AUGUST 2019
Hybrid rye for sows

- Satiety
- Growth
- Nutrition
- Health
- Immune function
- Stress
- Milk production
- Laxation
Sow dietary treatments

FORMULATED FOR GESTATION + LACTATION

Control: Corn/SBM

- Corn
- SBM
- Other

SB hulls, SB oil, vitamins, minerals
Sow dietary treatments
FORMULATED FOR GESTATION + LACTATION

- Other
- SBM
- Hybrid Rye
- Corn

SB hulls, SB oil, vitamins, minerals

Replaces 25% of corn with hybrid rye
Sow dietary treatments

FORMULATED FOR GESTATION + LACTATION

- Replaces 50% of corn with hybrid rye
- SB hulls, SB oil, vitamins, minerals
- Other
- Corn
- SBM
- Hybrid Rye

FORMULATED FOR GESTATION + LACTATION
Sow dietary treatments
FORMULATED FOR GESTATION + LACTATION

Replaces 75% of corn with hybrid rye

Hybrid Rye
SBM
Other
Corn
SB hulls, SB oil, vitamins, minerals
Methods

Body weights: Sows and/or piglets
Serum: IgG, IgA, IL-1β, IL-6, TNF-α
Milk: IgG, IgA, SCC, MUN, fat, protein, lactose

Days of gestation:
- BREED: 0
- ALLOT: 7
- BUMP FEED: 90
- MOVE TO LACTATION: 105
- FARROW: ~115

Days of lactation:
- SAMPLE: 13
- WEAN: 21
**Gestation Data**

**Initial BW, kg**

- **Linear** $P = 0.532$
- **Quadratic** $P = 0.166$

**Day 105 BW, kg**

- **Linear** $P = 0.536$
- **Quadratic** $P = 0.192$
GESTATION DATA

**Sow ADG, kg**

- Control
- 17.5% Rye
- 35% Rye
- 52.5% Rye

*Linear* $P = 0.817$

*Quadratic* $P = 0.623$

**Sow ADFI, kg**

- Control
- 17.5% Rye
- 35% Rye
- 52.5% Rye

*Linear* $P = 0.812$

*Quadratic* $P = 0.466$
Results: Gestation

\[ P > 0.05 \]

- Initial Body Weight, kg
- Day 105 Body Weight, kg
- Average Daily Gain, kg
- Average Daily Feed Intake, kg

Hybrid rye inclusion rate of 52.5% appears to have little to no effect on gestation performance.

If no ergot is present, it is predicted that 70% hybrid rye in gestation diets would also be safe.
SOW LACTATION DATA

**Farrow BW, kg**

- Control
- 17.5% Rye
- 35% Rye
- 52.5% Rye

Linear $P = 0.613$

Quadratic $P = 0.507$

**Wean BW, kg**

- Control
- 17.5% Rye
- 35% Rye
- 52.5% Rye

Linear $P = 0.989$

Quadratic $P = 0.861$
**SOW LACTATION DATA**

### ADG, kg

<table>
<thead>
<tr>
<th></th>
<th>Linear P</th>
<th>Quadratic P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.474</td>
<td></td>
</tr>
<tr>
<td>17.5% Rye</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35% Rye</td>
<td></td>
<td></td>
</tr>
<tr>
<td>52.5% Rye</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### ADFI, kg

<table>
<thead>
<tr>
<th></th>
<th>Linear P</th>
<th>Quadratic P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.520</td>
<td>0.134</td>
</tr>
<tr>
<td>17.5% Rye</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35% Rye</td>
<td></td>
<td></td>
</tr>
<tr>
<td>52.5% Rye</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Total born, pigs**

- Control: 16
- 17.5% Rye: 18
- 35% Rye: 17
- 52.5% Rye: 14

Linear: $P = 0.401$

Quadratic: $P = 0.334$

**Live born, pigs**

- Control: 14
- 17.5% Rye: 15
- 35% Rye: 16
- 52.5% Rye: 14

Linear: $P = 0.593$

Quadratic: $P = 0.324$
Weaned, pigs

- Linear $P = 0.904$
- Quadratic $P = 0.113$

Mortality, %

- Linear $P = 0.002$
- Quadratic $P = 0.028$
Mortality Data

Pigs crushed

- Linear $P = 0.072$
- Quadratic $P = 0.783$

Low vitality pigs

- Linear $P = 0.454$
- Quadratic $P = 0.712$
**Total litter wt., kg**

- **Control**: 20 kg
- **17.5% Rye**: 25 kg
- **35% Rye**: 30 kg
- **52.5% Rye**: 25 kg

*Linear P = 0.048*

*Quadratic P = 0.072*

**Live litter wt., kg**

- **Control**: 20 kg
- **17.5% Rye**: 22 kg
- **35% Rye**: 24 kg
- **52.5% Rye**: 20 kg

*Linear P = 0.253*

*Quadratic P = 0.189*
PIGLET DATA

**Litter wean wt., kg**

- Control
- 17.5% Rye
- 35% Rye
- 52.5% Rye

**Litter ADG, kg**

- Control
- 17.5% Rye
- 35% Rye
- 52.5% Rye

**Linear**
- P = 0.631

**Quadratic**
- P = 0.023

**Linear**
- P = 0.490

**Quadratic**
- P = 0.006
**Avg. live wt., kg**

- Control: 1.4
- 17.5% Rye: 1.5
- 35% Rye: 1.6
- 52.5% Rye: 1.7

*Linear* $P = 0.511$

*Quadratic* $P = 0.521$

---

**Avg. wean wt., kg**

- Control: 6.0
- 17.5% Rye: 6.5
- 35% Rye: 7.0
- 52.5% Rye: 7.5

*Linear* $P = 0.551$

*Quadratic* $P = 0.358$

---

**PIGLET DATA**
Results: Lactation

PRELIMINARY CONCLUSIONS:

Hybrid rye in lactation diets results in no reduction in sow or piglet performance. Mortality was reduced as hybrid rye inclusion in the diet increased.
Upcoming research
Taste preference

Comparative energy utilization
Growth performance

- Blood serum
- Fecal scores
- Body weights
- Feed intake
- Carcass characteristics
- Taste panel