Nutritional Value of Hybrid Rye for Pigs

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Outline

BACKGROUND

DIGESTIBLE NUTRIENTS

PIG PERFORMANCE
Hybrid Rye
Hybrid Rye *for pigs*

**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
SID = 64%

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

<table>
<thead>
<tr>
<th>Grain Type</th>
<th>Undigested Lys, %</th>
<th>Digested Lys, %</th>
<th>Total Lys, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hybrid Rye</td>
<td>62% (\text{b})</td>
<td>77% (\text{a})</td>
<td>77% (\text{a})</td>
</tr>
<tr>
<td>DH Barley</td>
<td></td>
<td>77% (\text{a})</td>
<td>79% (\text{a})</td>
</tr>
<tr>
<td>Wheat</td>
<td></td>
<td></td>
<td>78% (\text{a})</td>
</tr>
<tr>
<td>Corn</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(P < 0.05\)

*Note: [Lys] in grain refers to the total lysine content in the grain.*
Digestible Methionine (SID)

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

P < 0.05
Digestible Threonine (SID)

<table>
<thead>
<tr>
<th>Grain Type</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>81% a</td>
<td>80% a</td>
</tr>
<tr>
<td>DH Barley</td>
<td>31% b</td>
<td>81% a</td>
<td>80% a</td>
</tr>
<tr>
<td>Wheat</td>
<td>31% b</td>
<td>80% a</td>
<td>80% a</td>
</tr>
<tr>
<td>Corn</td>
<td>31% b</td>
<td>82% a</td>
<td>82% a</td>
</tr>
</tbody>
</table>

*P < 0.05*
Digestible Tryptophan (SID)

<table>
<thead>
<tr>
<th>Grain</th>
<th>Tryptophan, %</th>
<th>Undigested</th>
<th>Digested</th>
<th>Total [Trp] in grain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hybrid Rye</td>
<td>72% b</td>
<td>9% b</td>
<td>63% b</td>
<td></td>
</tr>
<tr>
<td>DH Barley</td>
<td>88% a</td>
<td>0% a</td>
<td>88% a</td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td>90% a</td>
<td>0% a</td>
<td>90% a</td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>89% a</td>
<td>0% a</td>
<td>89% a</td>
<td></td>
</tr>
</tbody>
</table>

\( P < 0.05 \)
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
EXP. 2

Phosphorus Digestibility

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 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
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>Undigested</th>
<th>Digested</th>
<th>Total [P] in grain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rye</td>
<td>49%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barley</td>
<td>45%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td>37%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn</td>
<td>25%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sorghum</td>
<td>17%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Digestible Phosphorus (STTD)

<table>
<thead>
<tr>
<th></th>
<th>Undigested</th>
<th>Digested</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rye -</td>
<td>0.29</td>
<td>0.13</td>
<td>0.39</td>
</tr>
<tr>
<td>Rye +</td>
<td>0.26</td>
<td>0.12</td>
<td>0.38</td>
</tr>
<tr>
<td>Barley -</td>
<td>0.25</td>
<td>0.10</td>
<td>0.35</td>
</tr>
<tr>
<td>Barley +</td>
<td>0.19</td>
<td>0.08</td>
<td>0.27</td>
</tr>
<tr>
<td>Wheat -</td>
<td>0.31</td>
<td>0.16</td>
<td>0.47</td>
</tr>
<tr>
<td>Wheat +</td>
<td>0.29</td>
<td>0.16</td>
<td>0.45</td>
</tr>
<tr>
<td>Corn -</td>
<td>0.25</td>
<td>0.05</td>
<td>0.31</td>
</tr>
<tr>
<td>Corn +</td>
<td>0.22</td>
<td>0.13</td>
<td>0.36</td>
</tr>
<tr>
<td>Sorghum -</td>
<td>0.30</td>
<td>0.15</td>
<td>0.45</td>
</tr>
<tr>
<td>Sorghum +</td>
<td>0.27</td>
<td>0.15</td>
<td>0.42</td>
</tr>
</tbody>
</table>
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
Starch (AID)

$P < 0.05$

<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>

Notes: 
- Values with different superscripts (a, b, ab) indicate significant differences at the $P < 0.05$ level.
Total dietary fiber (ATTD)

- **Rye**: 68%a
- **Barley**: 56%b
- **Wheat**: 58%b
- **Corn**: 58%b
- **Sorghum**: 58%b

*Undigested & Digested Total [TDF] in grain*

*P* < 0.05
<table>
<thead>
<tr>
<th>Crop</th>
<th>kcal/kg (DMB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rye</td>
<td>c</td>
</tr>
<tr>
<td>Barley</td>
<td>d</td>
</tr>
<tr>
<td>Wheat</td>
<td>ab</td>
</tr>
<tr>
<td>Corn</td>
<td>a</td>
</tr>
<tr>
<td>Sorghum</td>
<td>bc</td>
</tr>
</tbody>
</table>

P < 0.05

Metabolizable energy, kcal/kg DMB
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

ILLINOIS
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

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

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
Sow dietary treatments
FORMULATED FOR GESTATION + LACTATION

- Hybrid Rye
- SBM
- Other
- Corn

Replaces 75% of corn with hybrid rye

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

- BREED
- ALLOT
- BUMP FEED
- MOVE TO LACTATION
- FARROW
- SAMPLE
- WEAN

0 7 90 105 ~115 13 21 days of gestation days of lactation
**GESTATION DATA**

**Initial BW, kg**

- Control: 200 kg
- 17.5% Rye: 225 kg
- 35% Rye: 250 kg
- 52.5% Rye: 275 kg

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

**Day 105 BW, kg**

- Control: 300 kg
- 17.5% Rye: 325 kg
- 35% Rye: 350 kg
- 52.5% Rye: 375 kg

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

**Sow ADG, kg**

- **Linear** $P = 0.817$
- **Quadratic** $P = 0.623$

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Sow ADG, kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.7</td>
</tr>
<tr>
<td>17.5% Rye</td>
<td>0.7</td>
</tr>
<tr>
<td>35% Rye</td>
<td>0.7</td>
</tr>
<tr>
<td>52.5% Rye</td>
<td>0.7</td>
</tr>
</tbody>
</table>

**Sow ADFI, kg**

- **Linear** $P = 0.812$
- **Quadratic** $P = 0.466$

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Sow ADFI, kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>3.0</td>
</tr>
<tr>
<td>17.5% Rye</td>
<td>3.0</td>
</tr>
<tr>
<td>35% Rye</td>
<td>3.0</td>
</tr>
<tr>
<td>52.5% Rye</td>
<td>3.0</td>
</tr>
</tbody>
</table>
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: 250 kg
- 17.5% Rye: 300 kg
- 35% Rye: 350 kg
- 52.5% Rye: 400 kg

**Wean BW, kg**

- Control: 250 kg
- 17.5% Rye: 300 kg
- 35% Rye: 350 kg
- 52.5% Rye: 400 kg

**Linear**

- Farrow BW: $P = 0.613$
- Wean BW: $P = 0.989$

**Quadratic**

- Farrow BW: $P = 0.507$
- Wean BW: $P = 0.861$
**SOW LACTATION DATA**

**ADG, kg**

- **Linear** $P = 0.474$
- **Quadratic** $P = 0.476$

<table>
<thead>
<tr>
<th>Treatment</th>
<th>ADG, kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>-1.1</td>
</tr>
<tr>
<td>17.5% Rye</td>
<td>-0.9</td>
</tr>
<tr>
<td>35% Rye</td>
<td>-0.7</td>
</tr>
<tr>
<td>52.5% Rye</td>
<td>-0.5</td>
</tr>
</tbody>
</table>

**ADFI, kg**

- **Linear** $P = 0.520$
- **Quadratic** $P = 0.134$

<table>
<thead>
<tr>
<th>Treatment</th>
<th>ADFI, kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>5.0</td>
</tr>
<tr>
<td>17.5% Rye</td>
<td>4.5</td>
</tr>
<tr>
<td>35% Rye</td>
<td>3.5</td>
</tr>
<tr>
<td>52.5% Rye</td>
<td>2.5</td>
</tr>
</tbody>
</table>
**Total born, pigs**

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

**Linear** $P = 0.401$

**Quadratic** $P = 0.334$

**Live born, pigs**

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

**Linear** $P = 0.593$

**Quadratic** $P = 0.324$
PIGLET DATA

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**

- **Linear** $P = 0.048$
- **Quadratic** $P = 0.072$

- **Control** 22 kg
- **17.5% Rye** 24 kg
- **35% Rye** 26 kg
- **52.5% Rye** 20 kg

**Live litter wt., kg**

- **Linear** $P = 0.253$
- **Quadratic** $P = 0.189$

- **Control** 19 kg
- **17.5% Rye** 21 kg
- **35% Rye** 19 kg
- **52.5% Rye** 15 kg

*Source: ILLINOIS*
**Avg. live wt., kg**

- **Linear** $P = 0.511$
- **Quadratic** $P = 0.521$

**Avg. wean wt., kg**

- **Linear** $P = 0.551$
- **Quadratic** $P = 0.358$

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>17.5% Rye</th>
<th>35% Rye</th>
<th>52.5% Rye</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Avg. live wt.</strong></td>
<td>1.4</td>
<td>1.5</td>
<td>1.6</td>
<td>1.7</td>
</tr>
<tr>
<td><strong>Avg. wean wt.</strong></td>
<td>6.0</td>
<td>6.2</td>
<td>6.3</td>
<td>6.5</td>
</tr>
</tbody>
</table>

*Source: ILLINOIS*
**Avg. pig ADG, kg**

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

**Linear** $P = 0.228$

**Quadratic** $P = 0.198$

---

**Est. milk/d, kg**

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

**Linear** $P = 0.488$

**Quadratic** $P = 0.035$
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