Resistant Starch – A Comparative Nutrition Review

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Personal Background Education

• B.S. – Kansas State University
  – Animal Sciences & Industry

• M.S. – Oklahoma State University
  – Equine Nutrition

• Ph.D. – Kansas State University
  – USDA Fellow – Nutrition + Grain Science
    • Comparative Nutrition - Humans + Monogastic Animals
Personal Background

Professional

• Technical Nutritionist – Nestle Purina
  – Began as nutritionist for Friskies, Purina One and Pro plan
  – Managed Purina Veterinary Diet product formulation and development

• Assistant Professor – Kansas State University
  – Equine Nutrition
  – Broad comparative research program
    • Digestive physiology, microbiome
Starch

• Polysaccharides of alpha 1-4 and 1-6 linkages
• Starch granule consists of amylose and amylopectin
  – Amylose – linear polymer
  – Amylopectin – highly branched polymer
Effect of Waxy Corn on Broiler Performance
Collins et al. (2003)

Body Weight, g

18 days
42 days
49 days

Normal
Waxy

*
Types of Starch Based on Hydrolysis

• Rapidly Digestible Starch
  – Converted to glucose within 20 minutes of enzyme digestion i.e. cooked starch in a potato

• Slowly Digestible Starch
  – Completely digested in the SI but slower than RDS i.e. raw starch in a cereal grain

• Resistant Starch
  – Completely amylase resistant
Resistant Starch

- Fraction of starch which resists hydrolysis in the small intestine
- Thus, reaching the large intestine to undergo fermentation via the gut microbiome
  - Similar to a soluble, fermentable fiber
- Naturally found in
  - Cereal grains
  - Vegetables
  - Legumes
- Also synthetically made
Types of Resistant Starch

• Type 1
  – Inaccessible starch within cell wall other food matrixes
• Type 2
  – Native starch granules protected from digestion due to structure of the granule itself
• Type 3
  – Retrograded or nongranular starch formed after cooking and cooling
• Type 4
  – Chemically modified starch (cross linked, esterified, etc)
• Type 5
  – Amylose-lipid complex resistant to swelling and hydrolysis
Is resistant starch an ingredient?
In vitro digestibility of starch in a variety of foods (BNF 1990)

<table>
<thead>
<tr>
<th>Food</th>
<th>% RDS</th>
<th>% SDS</th>
<th>% RS1</th>
<th>% RS2</th>
<th>% RS3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flour, white</td>
<td>38</td>
<td>59</td>
<td>-</td>
<td>3</td>
<td>Traces</td>
</tr>
<tr>
<td>Bread, white</td>
<td>94</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Peas, cooked</td>
<td>56</td>
<td>24</td>
<td>11</td>
<td>Traces</td>
<td>6</td>
</tr>
<tr>
<td>Kidney beans, cooked</td>
<td>25</td>
<td>-</td>
<td>-</td>
<td>15</td>
<td>60</td>
</tr>
</tbody>
</table>

Is resistant starch still resistant starch after extrusion or retort?
Nutritional Implications of RS

• Increased laxation/fecal bulking
• Prebiotic
  – Improved gut health
• Reduced postprandial glycemia/insulinemia
• Reduced caloric density
  – While maintaining acceptable mouth feel
• Improved serum lipid profile
Laxation/Fecal Bulking
Murray et al. (1998)

• Fecal wet and dry weights increased 75% for dogs consuming a RS diet when compared to the control
  – Dry weights approximately 59 g/d greater
Laxation/Fecal Bulking

- Contradicting data regarding fecal quality
- Feces from dogs receiving RS diet were better formed (Murray et al., 1998)
- Inverse relationship between fecal score and RS supplementation (Goudeze et al., 2011)
  - But only occurred in large breeds; small breeds were unaffected
RS as a Prebiotic

• RS is fermented by hindgut microflora
  – Provides energy to 100’s of bacterial species
• Produces SCFA (or VFA)
  – Acetate, propionate and butyrate
  – RS produces a high proportion of butyrate
RS as a Prebiotic

• Butyrate is the major energy substrate for colonocytes
• Butyrate inhibits initiation and growth of colon tumors
• Fermentable substrates promote the growth of commensal microflora
  – Lactobacilli and bifidobacteria
RS Improves Luminal Environment
Nofrarias et al. (2007)

- 16 pigs fed raw potato starch (RPS) or corn starch (CS) for 14 wks
- Observations (P <0.05) in RPS pigs
  - Colon butyrate concentration was two-fold higher
  - Reduced apoptosis in intestinal crypts
  - Increase mucin sulfatation
    • Indicates greater mucin maturity and increased protection of intestinal epithelium
  - Reduced luminal magnesium
    • Associated with reduced epithelial cell damage
  - Lower colonic pH
**Symbiotic with Probiotics**

- Probiotics encapsulated to protect against environmental and GI factors
- Iyer and Kailasapathy (2005)
  - Hi-maize™ provided maximum protection when compared to Raftiline® and Raftilose®
    - Viable counts of Lactobacillus increased significantly
    - Significantly increased survivability under in vitro acidic and bile salt conditions
Improve Glucose/Insulin Kinetics

• Many studies show decreased postprandial blood glucose and insulin due to RS
  – Most fail to maintain equal amount of available carbohydrate
• Al-Tamimi et al. (2010) controlled for non starch ingredients and available CHO
  – 80 g RS4 significantly reduced postprandial glucose and insulin levels
Weight Management

• Reducing caloric intake
  – Reduced caloric density of the diet
  – Increased satiety
  – Increase luminal viscosity

• Caloric value is almost half that of digestible starch
  – 1.9 kcal vs. 3.6 kcal
  – SCFA yield approximately 60-70% of the caloric value of glucose
Reduced Caloric Intake

• Pigs consuming 35% pregelatinized starch (PS) or 34% retrograded starch (RS) (Souza da Saliva et al., 2014)
  – RS diet resulted in a 3% reduction in ME intake and less time at the feeder

• Adults consuming 48 g of RS or placebo (Bodinham et al., 2009)
  – RS diet resulted in a 10% reduction in 24 h caloric intake
Altered Lipid Metabolism

• Many studies show improved lipid metabolism with RS containing diets
  – Decreased LDL and total cholesterol
  – Decreased TG
    • Conflicting data – many studies show TG increasing
  – Decreased NEFA

• Many fail to maintain isocaloric diets
  – Unable to make inferences – is it the RS or simply a decrease in caloric intake
Altered Lipid Metabolism - Mechanisms

• Increased post prandial fat oxidation (PPFO)
  – 5.4% RS increased PPFO by 23% (Higgins et al., 2004)
  • 10.7% had no effect
  – Howe et al. (1996) found no effect on fat oxidation due to RS over a 10 wk period
Figure 2.8. Fold change in hepatocyte CPT1α (A), myocyte CPT1β (B), hepatocyte PGC-1α (C), and myocyte PGC-1α (D) mRNA abundance relative to day 0 in gilts after 42 d of a control (CON), high fiber (HF), or energy restricted (ER) diet.

A

B

C

D
Altered Lipid Metabolism - Mechanisms

• Decreased circulating NEFA concentrations
  – Decreased competition with glucose
• Increased bile secretion
  – Reducing total and LDL cholesterol
Several studies show an increase in plasma TG levels. Likely due to increased de novo lipogenesis via increased acetate.
Implications of RS in Pet Food

• Effective prebiotic and synergistic with probiotics
  – Gut health claim?
• Decreased caloric density
  – Weight maintenance diets
• Attenuates postprandial glycemia/insulinemia
  – Therapeutic vet diets
• Alters serum lipid profile
  – Therapeutic vet diets
• Enhanced texture and acceptability
Implications of RS in Pet Food

• How much RS does it take to make a claim?
• Does its efficacy really differ to that of a soluble fiber
  – Cheaper options
• Will consumers accept it?
  – Starch is a four letter word
• Does it comply to “natural” products?
Questions

"Large coffee and three bran muffins... hopefully to go!"