Potential Human Health Benefits of Dried Distiller’s Grains Solubles

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DDGS may have use in human food products

DDGS is a nutritious product for animal feeds

DDGS has components that make it potentially valuable as an ingredient for human foods

- Polyunsaturated fatty acids
- Antioxidants/phenolic acids
- Dietary fiber
- Xanthophylls

Establishing a human health benefit would greatly increase interest in DDGS for human use
Finding a suitable DDGS product

DDGS samples are processed in somewhat different ways at different plants

Aggressive drying conditions may damage the product

- Increase fat oxidation
- Reduce antioxidant capacity
- Produce undesirable Maillard reaction products

Thus, characterized a number of DDGS samples to find a suitable one for animal studies
DDGS samples vary in their antioxidant capacity

<table>
<thead>
<tr>
<th>DDGS Sample</th>
<th>Antioxidant Capacity (Tocopherol equivalents/100 g DDGS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DDGS#3</td>
<td>0</td>
</tr>
<tr>
<td>DDGS#5</td>
<td>1000</td>
</tr>
<tr>
<td>DDGS#10</td>
<td>2000</td>
</tr>
<tr>
<td>DDGS#15</td>
<td>3000</td>
</tr>
<tr>
<td>DDGS#16</td>
<td>4000</td>
</tr>
<tr>
<td>DDGS#18</td>
<td>5000</td>
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<tr>
<td>DDGS#19</td>
<td>6000</td>
</tr>
<tr>
<td>DDGS#20</td>
<td>7000</td>
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<tr>
<td>DDGS#21</td>
<td>4000</td>
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<td>DDGS#22</td>
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<td>DDGS#23</td>
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<tr>
<td>DDGS#26</td>
<td>1000</td>
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<tr>
<td>DDGS#27</td>
<td>2000</td>
</tr>
<tr>
<td>DDGS#29</td>
<td>3000</td>
</tr>
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</table>
There is great variation in lipid peroxidation of DDGS fat
DDGS vitamin E content varies, but is greater than corn.
Lightness, a marker for thermal damage, correlates with oxidation.
Sulfur content of DDGS is highly variable.
Ferulic acid in free (unbound) form may have great health benefits

The Zucker diabetic fatty (ZDF) rat	
Displays
✓ Obesity
✓ Hyperglycemia
✓ Insulin resistance
✓ Hyperlipidemia

Model for metabolic syndrome and type 2 diabetes with obesity

Diagram:
- Free ferulic acid
  - Increases
  - Body fat
  - Liver cholesterol
  - Insulin resistance
  - Glucose control
DDGS has a greater concentration of free ferulic acid than corn.

![Graph showing the concentration of ferulic acid in DDGS and corn.](image-url)
Corn is a rich source of xanthophylls

• Xanthophylls are a type of carotenoid

- Lutein
  A xanthophyll

- β-carotene

• Potential health benefits include –
  - Decreasing heart disease risk
  - Reducing macular degeneration
The main xanthophyll in all samples was lutein.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Xanthophyll Concentration (µg/100 g DDGS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DDGS#3</td>
<td>150</td>
</tr>
<tr>
<td>DDGS#5</td>
<td>70</td>
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<tr>
<td>DDGS#10</td>
<td>30</td>
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<tr>
<td>DDGS#15</td>
<td>10</td>
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<tr>
<td>DDGS#18</td>
<td>5</td>
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<tr>
<td>DDGS#20</td>
<td>2</td>
</tr>
<tr>
<td>DDGS#23</td>
<td>1</td>
</tr>
<tr>
<td>DDGS#25</td>
<td>0</td>
</tr>
<tr>
<td>Corn</td>
<td>0</td>
</tr>
</tbody>
</table>

Graph showing xanthophyll concentration (µg/100 g DDGS) for different samples.
Objectives of the first animal study

Determine effects of DDGS and other co-products on —

- Liver cholesterol
- Bile acid excretion
- Oxidative stress
- Xanthophyll bioavailability
Diet Groups

**Control** – purified diet

**DDGS** - Distiller’s Grains with Soluble Residue (20%)

**Bran Fraction** of Corn (20%)

**Soluble fraction** - Soluble Residue (20%) (DDS)

All diets were balanced for protein, carbohydrate, fat, and fiber:

- Cholesterol - 0.15%
- Fat - 15%
- Fiber - 9.5%
DDGS and co-products reduced liver cholesterol
DDGS and co-products increase bile acid excretion

<table>
<thead>
<tr>
<th>Fecal Bile Acids (mg/24 hr)</th>
<th>Control</th>
<th>DDGS</th>
<th>Bran fraction</th>
<th>Soluble fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a</td>
<td>bc</td>
<td>c</td>
<td>ab</td>
</tr>
</tbody>
</table>

- Control
- DDGS
- Bran fraction
- Soluble fraction

Cholesterol

Cholic acid (a bile acid)
Bile acid excretion does not correlate with liver cholesterol

![Graph showing the relationship between daily bile acid excretion and liver cholesterol levels. The correlation coefficient, R^2, is 0.15.](image-url)
DDGS and co-products did not alter a marker of oxidative stress
Determination of bioavailability of xanthophylls in DDGS and co-products is in progress

- Plasma concentrations of xanthophylls in rats fed DDGS is too low to detect
- Will determine xanthophyll concentration in tissues collected at end of feeding trial
- Analyze by LC-MS
Objective of the second study

Determine whether DDGS, dried condensed distiller’s solubles (DDS), or corn bran would reduce plasma cholesterol and atherosclerosis.
Apo E-deficient knockout mouse – a model of atherosclerosis

Mutation results in a marked increase in total plasma cholesterol levels

Fatty streaks occur in the aorta by around 3 months

Fatty streaks progress to atherosclerotic lesions
## Diet Groups

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<th>Diet Group</th>
<th>Description</th>
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<tr>
<td><strong>Control</strong></td>
<td>purified diet</td>
</tr>
<tr>
<td><strong>Bran Fraction</strong> of Corn (20%)</td>
<td></td>
</tr>
<tr>
<td><strong>DDGS</strong> - Distiller’s Grains with Soluble Residue (20%)</td>
<td></td>
</tr>
<tr>
<td><strong>Soluble fraction</strong> - Soluble Residue (20%) (DDS)</td>
<td></td>
</tr>
</tbody>
</table>

All diets were balanced for protein, carbohydrate, fat, and fiber:

- Cholesterol - 0.15%
- Fat - 15%
- Fiber - 9.5%
Mice grow normally when fed DDGS or other co-products
Total Serum Cholesterol

- **Control**
- **DDGS**
- **Soluble fraction**
- **Bran fraction**

**Day 30** vs **End of study**

- **Serum Cholesterol (mg/100 mL)**
- **Diet Group**

![Graph showing serum cholesterol levels across different diet groups at Day 30 and End of study.](chart.jpg)
Atherosclerotic lesion area

Atherosclerosis indicated by red stain

Diet Group

Lesion Area (as % of total area)

Arch %

Tree %

Control

DDGS

Soluble fraction

Bran fraction

University of Minnesota
In progress - measurement of coronary aortic root

- Determine blockage of aortic root
- Will complement atherosclerosis lesion area
Summary of animal studies

Cholesterol

• In rats, DDGS and co-products lowered liver cholesterol and increased bile acid excretion
• No effect on serum cholesterol in apoE-deficient mice

No effect on one marker of oxidative stress

Trend toward reduction in atherosclerosis lesion area with DDGS
Conclusions

DDGS may have *some* benefit in reducing heart disease risk

If DDGS and other co-products show tissue accumulation of xanthophylls, this will be viewed as a significant health benefit
Acknowledgements

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