NUTRITIONAL QUALITY OF EGGS FROM HENS FED WITH DDGS

Yan Zhang
National Corn to Ethanol Research Center
Southern Illinois University Edwardsville
and
Jill K. Winkler-Moser
National Center for Agricultural Utilization Research
USDA

22nd Distillers Grains Symposium
May 16, 2018
Nutritional quality of eggs from hens fed distillers dried grains with solubles

S. Trupia, J. K. Winkler-Moser, A. C. Guney, R. Beckstead, C.-Y. O. Chen

Poultry Science, Volume 95, Issue 11, 1 November 2016, Pages 2592–2601
https://doi.org/10.3382/ps/pew142
Project Funded by:
Iowa, Indiana and Illinois Corn Marketing Boards

• National Corn to Ethanol Research Center (NCERC) at Southern Illinois University Edwardsville
• University of Georgia
• USDA/NCAUR
• Tufts University USDA Jean Mayer Human Nutrition Research Center on Aging
Project Objectives

• Effect* of Regular and Low-fat DDGS addition at 10% or 20% to layer diets on growth, production (eggs/day), and egg quality (Food production)

• Effect on egg nutritional quality: lipids, amino acids and minerals (Food quality)

* Effect was evaluated by ANOVA and Tukey pairwise comparison
Animal Trial Design

- 150 Hyline W-36 White Leghorn hens 21 – 41 weeks
- 5 diets (control, 10% DDGS, 20% DDGS, 10% low fat DDGS and 20% low fat DDGS)
- 10 replicates (3 laying hens) for each diet
- Data collection: every 4, 5 weeks, 10 weeks and at the end of 20 weeks
Animal Trial Design
Animal Production Data Collection

- Feed intake (g/bird/day)
- Feed efficiency (feed intake / egg weight)
- Body weight gain (g)
- Egg production
- Egg mass (g)
- Egg specific gravity
- Egg color (L*a*b*)
Laboratory Data Collection

NCAUR
- Lipid extraction
- Fatty acid composition
- Xanthophylls
- Vitamin E
- Cholesterol
- Phospholipids

NCERC
- Sample processing
- Proximates
- Amino acids
- Minerals

Jean Mayer USDA
Human Nutrition Research Center on Aging

Jean Mayer USDA
Human Nutrition Research Center on Aging

Antioxidant capacity
MDA and FRAP
Calculated Content of Experimental Diets

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Control</th>
<th>10% DDGS</th>
<th>20% DDGS</th>
<th>10% LF DDGS</th>
<th>20% LF DDGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>TME, kcal/kg</td>
<td>2,890</td>
<td>2,890</td>
<td>2,890</td>
<td>2,890</td>
<td>2,890</td>
</tr>
<tr>
<td>CP, %</td>
<td>18.5</td>
<td>18.5</td>
<td>18.5</td>
<td>18.5</td>
<td>18.5</td>
</tr>
<tr>
<td>Ca, %</td>
<td>4.76</td>
<td>4.76</td>
<td>4.76</td>
<td>4.76</td>
<td>4.76</td>
</tr>
<tr>
<td>P, %</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Lysine, %</td>
<td>0.96</td>
<td>0.96</td>
<td>0.96</td>
<td>0.96</td>
<td>0.96</td>
</tr>
<tr>
<td>Total TSAA, %</td>
<td>0.80</td>
<td>0.80</td>
<td>0.80</td>
<td>0.80</td>
<td>0.80</td>
</tr>
</tbody>
</table>

*Formulated to meet Hy-Line variety W-36 commercial management guidelines*
## Composition of Experimental Diets

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Control</th>
<th>10% DDGS</th>
<th>20% DDGS</th>
<th>10% LF DDGS</th>
<th>20% LF DDGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>49.6</td>
<td>45.7</td>
<td>41.8</td>
<td>45.1</td>
<td>40.6</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>30.5</td>
<td>25.0</td>
<td>19.5</td>
<td>25.1</td>
<td>19.8</td>
</tr>
<tr>
<td>DDGS</td>
<td>-</td>
<td>10.0</td>
<td>20.0</td>
<td>10.0</td>
<td>20.0</td>
</tr>
<tr>
<td>Poultry fat</td>
<td>5.5</td>
<td>4.8</td>
<td>4.2</td>
<td>5.3</td>
<td>5.1</td>
</tr>
</tbody>
</table>

Other ingredients: Limestone (11%), dicalcium phosphate (2.2-2.4%), salt, minerals, vitamins, DL-methionine (0.25-0.27%), L-Lysine (0.06-0.30%), L-threonine (0.04-0.11%)
# Proximate Analyses of DDGS

<table>
<thead>
<tr>
<th></th>
<th>Moisture%</th>
<th>Protein%</th>
<th>Fat%</th>
<th>Fiber%</th>
<th>Ash%</th>
</tr>
</thead>
<tbody>
<tr>
<td>DDGS</td>
<td>11.2</td>
<td>30.7</td>
<td>13.3</td>
<td>7.3</td>
<td>4.9</td>
</tr>
<tr>
<td>Low-Fat DDGS</td>
<td>10.1</td>
<td>30.6</td>
<td>7.4</td>
<td>6.5</td>
<td>4.9</td>
</tr>
</tbody>
</table>
Feed Intake

No significant effect of DDGS treatment on feed intake
Egg Color

Different letter representing significant statistical difference

**KEY:**
- **L***: 0=black; 100=white
- **a*** - = green; + = red
- **B*** - = blue; + = yellow

Minolta Colorimeter
Main Effect Treatment Difference

No significant effect of DDGS treatment on feed efficiency, body gain weight, egg weight

Significant effect of DDGS treatment on

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>10% DDGS</th>
<th>20% DDGS</th>
<th>10% LF DDGS</th>
<th>20% LF DDGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg Production</td>
<td>a, b, c</td>
<td>b, c</td>
<td>a, b</td>
<td>c</td>
<td>a</td>
</tr>
<tr>
<td>Egg specific gravity</td>
<td>a</td>
<td>c</td>
<td>a, b</td>
<td>b</td>
<td>c</td>
</tr>
</tbody>
</table>
Food Quality

Oil

Protein

Minerals
## Composition of Egg Yolk

https://ndb.nal.usda.gov/ndb/search/list

<table>
<thead>
<tr>
<th>Proximates (g per 100 g)</th>
<th>Water</th>
<th>Protein</th>
<th>Total Lipid</th>
<th>Carbohydrates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>52.3</td>
<td>15.9</td>
<td>26.5</td>
<td>3.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total lipids (g per 100 g)</th>
<th>Total saturated fatty acids</th>
<th>Total monounsaturated fatty acids</th>
<th>total polyunsaturated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9.6</td>
<td>11.8</td>
<td>4.2</td>
</tr>
</tbody>
</table>

Ratio of total saturated to total unsaturated = 0.6

<table>
<thead>
<tr>
<th>Vitamins (mg/kg)</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
<td>4</td>
<td>0.5</td>
<td>26</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Minerals (mg/kg)</th>
<th>Calcium</th>
<th>Iron</th>
<th>Phosphorus</th>
<th>Potassium</th>
<th>Sodium</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1290</td>
<td>27</td>
<td>3900</td>
<td>1090</td>
<td>480</td>
</tr>
</tbody>
</table>
Oil and Oil Loving Nutrients

• About 2 - 3 times oil level in DDGS in comparison with in corn
• Enriched levels of omega 3 fatty acids from corn oil
• Enriched levels of carotenoids from corn oil
• Enriched levels of vitamin E from corn oil
• Enriched levels of antioxidants from corn oil and yeast
# Fatty Acid Composition of Diets

<table>
<thead>
<tr>
<th>(% in total lipid, wt/wt)</th>
<th>16:0</th>
<th>16:1</th>
<th>18:0</th>
<th>18:1</th>
<th>18:2</th>
<th>18:3 (omega-3)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DDGS</strong></td>
<td>11.33</td>
<td>0.1</td>
<td>1.7</td>
<td>27.0</td>
<td>57.7</td>
<td>1.5</td>
</tr>
<tr>
<td><strong>Low-Fat DDGS</strong></td>
<td>11.9</td>
<td>0.1</td>
<td>1.9</td>
<td>27.4</td>
<td>56.3</td>
<td>1.6</td>
</tr>
<tr>
<td><strong>Control</strong></td>
<td>19.91</td>
<td>4.3</td>
<td>4.6</td>
<td>35.6</td>
<td>32.5</td>
<td>1.9</td>
</tr>
<tr>
<td><strong>10% DDGS</strong></td>
<td>19.0</td>
<td>3.8</td>
<td>4.3</td>
<td>34.5</td>
<td>35.3</td>
<td>1.8</td>
</tr>
<tr>
<td><strong>20% DDGS</strong></td>
<td>16.3</td>
<td>2.8</td>
<td>3.4</td>
<td>32.3</td>
<td>41.3</td>
<td>1.8</td>
</tr>
<tr>
<td><strong>10% LF DDGS</strong></td>
<td>19.1</td>
<td>4.1</td>
<td>4.3</td>
<td>35.0</td>
<td>34.2</td>
<td>1.9</td>
</tr>
<tr>
<td><strong>20% LF DDGS</strong></td>
<td>19.4</td>
<td>4.1</td>
<td>4.4</td>
<td>35.0</td>
<td>33.9</td>
<td>1.7</td>
</tr>
</tbody>
</table>
Fatty Acid Composition of Egg Yolk Lipids

Fatty Acid Contents (% wt/wt in total lipid)

- 16:0
- 16:1
- 18:0
- 18:1
- 18:2
- 18:3

Statistically different

- control
- 10% DDGS
- 20% DDGS
- 10% LF-DDGS
- 20% LF-DDGS
Ratio of Total Saturated to Total Unsaturated (Egg Yolk)

No significant effect of DDGS treatment on ratio of TS to TUS

USDA Reference (0.60)

R-DDGS and LF-DDGS (0.16)
Xanthophylls

Impact on human health

• Antioxidants
• Protect eyes from development of cataracts and age-related macular degeneration

Impact on poultry production

• Enhance skin color
• Enhance egg yolk color
# Xanthophylls in DDGS and Diet Formulations

<table>
<thead>
<tr>
<th>Component/Diet</th>
<th>Unknown</th>
<th>Lutein</th>
<th>Zeaxanthin</th>
<th>B-cryptoxanthin</th>
</tr>
</thead>
<tbody>
<tr>
<td>DDGS</td>
<td>3.73</td>
<td>39.26</td>
<td>9.73</td>
<td>3.40</td>
</tr>
<tr>
<td>Low-fat DDGS</td>
<td>1.57</td>
<td>15.70</td>
<td>9.35</td>
<td>3.27</td>
</tr>
<tr>
<td>Control</td>
<td>0.29</td>
<td>5.58</td>
<td>2.64</td>
<td>1.16</td>
</tr>
<tr>
<td>10% DDGS</td>
<td>0.60</td>
<td>10.15</td>
<td>4.09</td>
<td>1.96</td>
</tr>
<tr>
<td>20% DDGS</td>
<td>0.61</td>
<td>9.27</td>
<td>3.10</td>
<td>1.08</td>
</tr>
<tr>
<td>10% LF DDGS</td>
<td>0.37</td>
<td>5.80</td>
<td>3.01</td>
<td>1.52</td>
</tr>
<tr>
<td>20% LF DDGS</td>
<td>0.42</td>
<td>5.57</td>
<td>2.90</td>
<td>1.25</td>
</tr>
</tbody>
</table>
Xanthophylls in Egg Lipids

Control

10% DDGS

20% DDGS

10% Low-20% Low-fat DDGS

μg/egg lipid

β-cryptoxanthin
Zeaxanthin
Lutein
Unknown
Vitamin E
(tocopherols)

Impact on human health

• Anti-cancer
• Cholesterol lowering
• Neuroprotective
# Tocopherols in DDGS and Diets

<table>
<thead>
<tr>
<th>Component/Diet</th>
<th>α-T</th>
<th>α-T3</th>
<th>β-T</th>
<th>γ-T</th>
<th>γ-T3</th>
<th>δ-T</th>
</tr>
</thead>
<tbody>
<tr>
<td>DDGS</td>
<td>175</td>
<td>91</td>
<td>10</td>
<td>633</td>
<td>145</td>
<td>13</td>
</tr>
<tr>
<td>Low fat DDGS</td>
<td>297</td>
<td>132</td>
<td>6</td>
<td>574</td>
<td>136</td>
<td>13</td>
</tr>
<tr>
<td>Diets</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>60</td>
<td>25</td>
<td>2</td>
<td>203</td>
<td>20</td>
<td>29</td>
</tr>
<tr>
<td>10% DDGS</td>
<td>77</td>
<td>38</td>
<td>2</td>
<td>242</td>
<td>39</td>
<td>25</td>
</tr>
<tr>
<td>20% DDGS</td>
<td>129</td>
<td>57</td>
<td>4</td>
<td>401</td>
<td>66</td>
<td>31</td>
</tr>
<tr>
<td>10% LF DDGS</td>
<td>86</td>
<td>36</td>
<td>3</td>
<td>257</td>
<td>33</td>
<td>29</td>
</tr>
<tr>
<td>20% LF DDGS</td>
<td>87</td>
<td>42</td>
<td>2</td>
<td>230</td>
<td>40</td>
<td>19</td>
</tr>
</tbody>
</table>

Units= μg/g extracted oil
Tocopherols in Egg Lipids

![Graph showing tocopherols in egg lipids](image-url)

- **α-T**: Control > 10% low-fat > 20% low-fat
- **α-T3**: Control > 20% DDGS > 10% DDGS
- **γ-T**: Control > 20% low-fat > 10% low-fat
- **Total**: Control > 20% DDGS > 10% DDGS

- **Control**
- **10% DDGS**
- **20% DDGS**
- **10% low-fat**
- **20% low-fat**
Cholesterol in Yolk Lipids

No significant effect of treatment on cholesterol content
Ferric Reducing Antioxidant Power (FRAP) of Feeds and DDGS
Malondialdehyde (MDA) and FRAP of Egg Yolk

No significant effect of DDGS in feeds on oxidation status or antioxidant capacity
Protein

• About three times protein level in DDGS in comparison with in corn
• Yeast contributes about extra 20% increase in protein level in DDGS
• Yeast contributes unique amino acid profile to DDGS also
Essential Amino-Acids (Egg Yolk)

No significant effect of DDGS treatment on any essential AA
Essential Amino-Acids (White)

Amino Acid Content (% dry basis)

Amino Acid Content in DDGS (% dry wt/ wt)

- Methionine
- Isoleucine
- Leucine
- Lysine
- Threonine
- Valine
- Histidine
- Phenylalanine
- Tryptophan

- Week 10-whites
- Week 10-whites
- Week 10-whites
- Week 10-whites
- Low fat DDGS
- Regular DDGS
No significant effect of DDGS treatment on total essential AA
Minerals

• About three times mineral levels in DDGS in comparison with in corn
• Enzymatic conversion helps to increase bioavailability of numerous minerals
Minerals in Egg Yolk

No significant effect of DDGS treatment on any minerals

- **USDA Iron 27 mg/kg**
  - eggs
  - feed

- **USDA Phosphorus 0.39%**
  - control
  - 10%
  - 20%
  - 10% feed
  - 20% feed

- **USDA Calcium 1290 mg/kg**
  - control
  - 10%
  - 20%
  - 10% feed
  - 20% feed

- **USDA Potassium 1090 mg/kg**
  - control
  - 10%
  - 20%
  - 10% feed
  - 20% feed

No significant effect of DDGS treatment on any minerals.
CONCLUSIONS

Regular and Low-Fat DDGS addition to layer diets

Food Production
a. no influence: feed intake, feed efficiency, body weight gain, egg weight
b. Yes influence: egg color, egg production and egg specific gravity

Food Quality
a. Egg yolk fatty acid composition: the ratio of total saturated to total unsaturated remained the same
b. No influence: cholesterol, antioxidant capacity, amino acid and minerals
c. Egg yolk from layers fed with DDGS had enhanced levels of xanthophylls and vitamin E
### Egg Yolk vs. DDGS

#### Proximates

<table>
<thead>
<tr>
<th>Proximates (g per 100 g)</th>
<th>Water</th>
<th>Protein</th>
<th>Total Lipid</th>
<th>Carbohydrates</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Egg Yolk</strong></td>
<td>52</td>
<td>16</td>
<td>27</td>
<td>4</td>
</tr>
<tr>
<td><strong>DDGS</strong></td>
<td>10</td>
<td>27</td>
<td>8</td>
<td>45</td>
</tr>
</tbody>
</table>
## Egg Yolk vs. DDGS

### Oil

<table>
<thead>
<tr>
<th></th>
<th>Total saturated</th>
<th>Total monounsaturated</th>
<th>total polyunsaturated</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Egg Yolk</strong></td>
<td>9.6</td>
<td>11.8</td>
<td>4.2</td>
</tr>
<tr>
<td><strong>DDGS</strong></td>
<td>1.1</td>
<td>2.2</td>
<td>4.6</td>
</tr>
</tbody>
</table>

**Egg Yolk**

Ratio of total saturated to total unsaturated = 0.60

**DDGS**

Ratio of total saturated to total unsaturated = 0.16

### Vitamins (mg/kg)

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Egg Yolk</strong></td>
<td>4</td>
<td>4</td>
<td>0.5</td>
<td></td>
<td>26</td>
</tr>
<tr>
<td><strong>DDGS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>93</td>
</tr>
</tbody>
</table>

---

Vitamins data includes:

- A: 4
- B: 4
- C: 0.5
- D: 
- E: 26

**DDGS**

- E: 93
## Egg Yolk vs. DDGS
*(Essential Amino Acids)*

<table>
<thead>
<tr>
<th>%, wt/wt</th>
<th>Control</th>
<th>10% R-DDGS</th>
<th>20% R-DDGS</th>
<th>10% L-DDGS</th>
<th>20% L-DDGS</th>
<th>L-DDGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methionine</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.7</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>1.1</td>
</tr>
<tr>
<td>Leucine</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
<td>1.3</td>
<td>3.5</td>
</tr>
<tr>
<td>Lysine</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.2</td>
<td>1.0</td>
</tr>
<tr>
<td>Threonine</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.8</td>
<td>1.1</td>
</tr>
<tr>
<td>Valine</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
<td>0.9</td>
<td>1.6</td>
</tr>
<tr>
<td>Histidine</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td>0.8</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>0.7</td>
<td>1.5</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.3</td>
</tr>
<tr>
<td><strong>Total Essential AA</strong></td>
<td><strong>6.6</strong></td>
<td><strong>6.6</strong></td>
<td><strong>6.6</strong></td>
<td><strong>6.5</strong></td>
<td><strong>6.8</strong></td>
<td><strong>11.6</strong></td>
</tr>
</tbody>
</table>
Egg Yolk vs. DDGS
(minerals)

<table>
<thead>
<tr>
<th>Minerals (mg /kg)</th>
<th>Calcium</th>
<th>Iron</th>
<th>Phosphorus</th>
<th>Potassium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Egg Yolk</td>
<td>1290</td>
<td>27</td>
<td>3900</td>
<td>1090</td>
</tr>
<tr>
<td>DDGS</td>
<td>546</td>
<td>146</td>
<td>9800</td>
<td>12450</td>
</tr>
</tbody>
</table>
Thank You!