Intrinsic Characteristics of Modified DDGS and Development of Effective Handling Strategies

Project Update

NC -213 Meeting, March 1-2
Austin, TX, 2016
Principal Investigators

Kingsly Ambrose
Purdue University
Mark Casada
USDA-ARS
Senay Simsek
NDSU

*Presented by Kaliramesh Siliveru, Graduate Research Assistant, KSU
Outline

• Introduction
• Objectives
• Materials and Methods
• Results
• Conclusions
Modified DDGS (M-DDGS)

- Low oil (4-5% fat) DDGS
- Increased profits in oil extraction
- Around 105 dry grind ethanol plant extracted oil (USGC, 2012) (50% of plants)
- Price of crude oil is $0.45/lb
- Oil extraction investment ~ $3 million, recovery period – 3 to 4 months

Introduction

About 30% corn oil is removed from Method 1 and 60% oil is removed from Method 2

Objectives

• Quantify the flow profile and mass flow rate of low-oil DDGS during hopper discharge.

• Develop a viable method to disrupt the pre-transportation bridges formed between low-oil DDGS particles and evaluate the effect of mechanical manipulation on improving the flowability.
Materials and Methods

• Sample collection
  – POET Nutrition (low-oil DDGS)
• Particle size and size distribution
  (ASABE Standard S 319.4)
• Flow property measurement for hopper construction:
  – FT4 Powder Rheometer
    – Shear cell measurements
• Hopper flow analysis
  – PIV Analysis
  – Particle segregation from hopper discharge
Materials and Methods

• Hopper flow Analysis
  – Moisture content (10 % w.b.)
  – Fat content (5.36 W/W)
  – Sample size – 66.7 lb
  – Ambient condition (20 °C, 55% RH)
  – Summer condition (35 °C, 45% RH)
  – Winter condition (0 °C, 85% RH)
  – Consolidation time (2, 4, 6, 8 days)
Materials and Methods

• Mechanical treatment of samples
  – Rotating cylindrical drum (16 rpm for 20 minutes)
  – Sample size – 66.7 lb
  – Summer condition (35 °C, 45% RH)
  – Winter condition (0 °C, 85% RH)
  – Consolidation time (2, 4, 6, 8 days)
Results

Flow Properties

At 10% moisture content (w.b.)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Stability index</td>
<td>1.30</td>
</tr>
<tr>
<td>Basic flowability energy, mJ</td>
<td>715</td>
</tr>
<tr>
<td>Cohesion, kPa</td>
<td>0.62</td>
</tr>
<tr>
<td>Flow function</td>
<td>5.16</td>
</tr>
<tr>
<td>Wall friction angle (steel), °</td>
<td>29.02</td>
</tr>
<tr>
<td>Effective angle of internal friction, °</td>
<td>38.61</td>
</tr>
</tbody>
</table>

** Values in the parenthesis represents standard errors.
Results

Hopper Parameters:

- Hopper opening (W) = 7.2 cm
- Semi-included angle (θ) = 30°
- Length of the hopper = 30.48 cm
- Height of the sample = 68.58 cm (66.7 lbs)

* Construction is based on FT 4 analysis and Jenike (1964) design charts.
## Results

Mass Flow Rate of samples without Mechanical Manipulation

<table>
<thead>
<tr>
<th>Consolidation time (Days)</th>
<th>Mass flow rate (lb/sec)</th>
<th>Room condition (20 °C, 50% r.h)</th>
<th>Summer condition (35 °C, 45% r.h)</th>
<th>Winter condition (0 °C, 85% r.h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>8.67 ± 0.38</td>
<td>No flow</td>
<td>No flow</td>
<td>No flow</td>
</tr>
<tr>
<td>4</td>
<td>8.92 ± 0.10</td>
<td>No flow</td>
<td>No flow</td>
<td>No flow</td>
</tr>
<tr>
<td>6</td>
<td>8.95 ± 0.22</td>
<td>No flow</td>
<td>No flow</td>
<td>No flow</td>
</tr>
<tr>
<td>8</td>
<td>8.78 ± 0.20</td>
<td>No flow</td>
<td>No flow</td>
<td>No flow</td>
</tr>
</tbody>
</table>
# Results

Mass Flow Rate of samples with Mechanical Manipulation

<table>
<thead>
<tr>
<th>Consolidation time (Days)</th>
<th>Mass flow rate (lb/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Summer condition (35 °C, 45% r.h)</strong></td>
</tr>
<tr>
<td>2</td>
<td>No flow</td>
</tr>
<tr>
<td>4</td>
<td>No flow</td>
</tr>
<tr>
<td>6</td>
<td>No flow</td>
</tr>
<tr>
<td>8</td>
<td>No flow</td>
</tr>
</tbody>
</table>
Results
Particle Image Velocimetry Analysis (PIV)

Velocity vectors

PIV Analysis

PIV with velocity profile
## Results

### Velocity at select height (cm/sec); Room conditions

<table>
<thead>
<tr>
<th>Consolidation Days</th>
<th>Position 1</th>
<th>Position 2</th>
<th>Position 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>5.06 ± 1.23</td>
<td>5.81 ± 0.71</td>
<td>5.75 ± 0.84</td>
</tr>
<tr>
<td>4</td>
<td>6.02 ± 1.08</td>
<td>5.35 ± 1.54</td>
<td>6.02 ± 1.08</td>
</tr>
<tr>
<td>6</td>
<td>5.91 ± 1.73</td>
<td>5.18 ± 1.42</td>
<td>5.33 ± 0.75</td>
</tr>
<tr>
<td>8</td>
<td>5.62 ± 0.96</td>
<td>5.62 ± 0.39</td>
<td>5.71 ± 0.48</td>
</tr>
</tbody>
</table>
Results

Particle Segregation

Sample collection after the discharge of low-oil DDGS from hopper.
## Results

### Particle Size Distribution

<table>
<thead>
<tr>
<th>Consolidation time (days)</th>
<th>Geometric mean particle diameter ($d_{gw}$, μm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Side</td>
</tr>
<tr>
<td>2</td>
<td>414.73 ± 2.05$^A$</td>
</tr>
<tr>
<td>4</td>
<td>413.63 ± 1.81$^A$</td>
</tr>
<tr>
<td>6</td>
<td>417.19 ± 1.73$^A$</td>
</tr>
<tr>
<td>8</td>
<td>416.03 ± 0.86$^A$</td>
</tr>
</tbody>
</table>

*Values with same upper case letters in a row are not significantly different for a particular day by least significant difference (LSD) comparison of means. ($\alpha = 0.05$)
Conclusions

- This study confirmed that environmental conditions have significant effect on flow behavior of low-oil DDGS.
- The mass flow rate ranged from 8.5 to 9.0 lb/sec at ambient conditions irrespective of consolidation time.
- The particle segregation study confirmed the variation in particle size within a pile of M-DDGS formed by gravity-driven discharge.
- The mechanical disruption of low oil DDGS agglomerates prior to loading does not have a significant effect on flow behavior.
Acknowledgements

• Rumela Bhadra, Post-Doctoral RA, KSU
• Kristen Whitney, NDSU
• Jeevan Upreti and Michael Pordesimo – Summer Interns, Grain Science and Industry, K-State

Thank You!