GEA Barr-Rosin

The Effects of Drying on DDGS Protein Quality

Kosta Kanellis
GEA Barr-Rosin, Naperville, IL USA
kosta.kanellis@gea.com
www.gea.com
Agenda

• Introduction
  • GEA Barr-Rosin Company Profile
  • DDGS Drying Experience

• Drying Fundamentals

• DDGS Drying Technologies

• DDGS Product quality

• Case Study

• Conclusions
GEA Barr-Rosin – Company Profile

Corporate Offices

- Boisbriand, Canada – est. in 1974, servicing North and South America
- Maidenhead, UK – est. in 1959, servicing Europe and Asia
- Fully Functional Pilot Plant Facilities for testing variety of products

- A worldwide leading supplier of drying systems with over sixty (60) years experience with over 2500 drying systems worldwide.
- Wide technology portfolio with strong agrifood focus including corn, wheat, rye, barley & soy feedstocks
First generation DDGS ring dryer installed in the late 70’s
Second generation mid 80’s, including energy integration
(Wheat DDGS dryers in Europe in operation for 20+ years)
The 3rd generation “Feed-Type Ring Dryer” for DDGS was installed in the US in 2002.
Barr-Rosin has supplied over 80 drying systems for DDGS and related DDG co-products to the US dry milling industry since 2002. This includes;
• Rotary Drying Systems for DDGS
• Ring Drying Systems for DDGS and High Protein DDG products
• Superheated Steam Dryers for DDGS
• Steam Tube Drying Systems for DDGS (in collaboration with Davenport Dryer LLC)
DDGS and Nutritional Quality

- Nutritionists want consistency and predictability in the feed ingredients they purchase and use. The nutrient content of DDGS can vary among DDGS sources.
- Numerous factors can influence the nutrient composition of the DDGS.
  - Raw Material (soil condition, fertilizer, weather…)
  - Processing Steps: (Grinding, Cooking, Distillation, Fermentation, Drying, Evaporation…)
- The most important factors affecting the variability of the nutrient content of DDGS are;
  - Variations in the nutrient content in the corn delivered to the plant
  - Variations of the mixture ratio of the syrup and wet cake
  - *Drying Process*
Drying Fundamentals
Drying Fundamentals

- Dryers always involve simultaneous heat and mass transfer
  - Heat is transferred from the drying medium to the product, thus cooling the drying medium
  - Solvent (water) in the product absorbs the majority of the heat and evaporates into the drying medium. If the product surface is wet, the evaporation happens without increasing the product temperature
  - The remainder of the heat is used for sensible heating of the product and the solvent
The Process of Evaporation
Typical Drying Curve

- Flash Dryers
- Ring Dryers
- SSD™ Dryers
- Spray Dryers

- Rotary Dryers
- Fluid Bed Dryers
- Paddle Dryers
DDGS Drying Technologies
Most four (4) most common types DDGS Drying Technologies installed at North American dry mill ethanol plants include:

- Rotary Drying Systems
- Ring Drying Systems
- Superheated Steam Dryers (SSD™)
- Rotary Steam Tube Dryers

Factors affecting Dryer Selection

- Reliability & Operability
- Product Quality (Consistency, Color, Odor, Nutrient Profile)
- Heat Source Available
- Energy Efficiency
- Flexibility to dry other co-products
- Emissions
- Footprint Available
- Particle Size
Traditional Drying Systems for DDGS
Rotary Drying System
Traditional Drying Systems for DDGS
Rotary Drying System
Traditional Drying Systems for DDGS

Rotary Drying System
Traditional Drying Systems for DDGS

Rotary Steam Tube Drying System
Traditional Drying Systems for DDGS

Ring Drying System
Traditional Drying Systems for DDGS

Ring Drying System
Traditional Drying Systems for DDGS
Superheated Steam Drying System
DDGS Drying and Product Quality

• Due to the variety of drying technologies, the design, and their operating conditions, the nutritional profile of the DDGS is fairly variable.

• The main factors affecting DDGS product quality during the drying process are:
  • Dryer operating temperatures
  • Product Residence time in the drying system
  • Wet Feed Conditioning (proper mixing)
  • Dryer Configuration

• Excessive heating of the product and reduced protein availability have been well documented
DDGS Drying and Product Quality

- The Maillard Reaction is a browning which involves a reaction of simple sugars and amino acids. The degree of color development (extent of Maillard reaction) can be calculated using the Cook Index

\[
Cook\ Index\ (It) = \left[ \frac{10^{15}}{3600} e^{-99/8.314} e^{-3T} \right] \times t
\]

where

\[T = \text{Temperature (K)}\]
\[t = \text{time (seconds)}\]

- The speed of reaction increases exponentially with temperature,
- For optimal product quality, the operating at the lowest temperature and shortest residence time is preferred.
Progression of Maillard Reaction

Maillard Rx

Cook Index

Time (s)

Temperature (°C)
DDGS Drying and Product Quality

• Lysine is the most sensitive amino acid to heat damage and the extent of heat-damage and varies among DDGS sources.

• Various Studies have been conducted and demonstrated that the color of the DDGS is correlated with the lysine digestibility of the product.

• Hunter and Minoilta calorimeters are used to predict the amino acid digestibility of the DDGS product quality. \( L^* = 0 \) – dark, \( L^* = 100 \), light).

  • Lighter colored DDGS samples \( (L^* > 50) \) DDGS have higher lysine digestibility.

  • Darker colored DDGS samples \( (L^* < 50) \) resulted in lower lysine digestibility and reduced growth performance in poultry and seine.

• Note: Other factors that can influence color of the product include;
  • Lower syrup addition to DDGS:
  • Amount of sugars
DDGS Nutritional Composition and Product Quality

**Fig. 1. Regression of digestible lys (%) and color (L*, b*)**

- $R^2 = 0.71$
- $R^2 = 0.74$

Objectives

Test Campaign conducted to optimize color of the DDGS product produced from a GEA Barr-Rosin ring drying system. In particular, the effects by adjusting the following parameters were evaluated:

- Combustion Excess Air
- External Product Recycle
- Dryer Inlet Air Temperature

Method

The dry mill ethanol plant had two (2) DDGS Ring dryers installed at the facility. The dryers were operated in parallel configuration so the composition of the feed material to two (2) drying systems were the same.

One dryer would serve as the “baseline” while the other dryer would have the parameters outlined above varied.
Traditional Drying Systems for DDGS
Ring Drying System
Case Study
DDGS Color Optimization – Effect of Excess Air

Excess Air Test

![Graph showing the effect of excess air on DDGS color optimization. The graph compares DAO, DBO, and FBC colors across baseline and sample points.](image-url)
Case Study
DDGS Color Optimization – External Recycle

External Recycle
Color vs Time

- DAO Color
- DBO Color
- FBC Color

GEA Process Engineering
Case Study
DDGS Color Optimization – Inlet Temperature
Conclusions

The effects on DDGS color from modifying the dryer parameters;

- **Excess Air**
  - No significant impact in color
- **External Product Recycle**
  - Decreasing external recycle would tend to increase color
- **Dryer Inlet Temperature**
  - Operating at higher inlet drying temperatures is shown to have the highest impact on color.
Conclusions

- The effects of drying on protein quality (lysine digestibility) of the DDGS is dependent primarily on operating temperature and product residence time in the Dryer.
- Optimal product quality is achieved with shortest residence time and low operating temperatures in the drying process.
- Selection of dryer technology and operating parameters which have a significant impact on product quality.