Energy Value of Corn Milling Co-Products in Swine

B. J. Kerr, USDA-ARS / P. V. Anderson, Iowa State University / G. C. Shurson, University of Minnesota
<table>
<thead>
<tr>
<th>Corn</th>
<th>Nutrient</th>
<th>DDGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>57.1</td>
<td>Starch</td>
<td>7.2</td>
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<tr>
<td>7.2</td>
<td>Crude Protein</td>
<td>28.3</td>
</tr>
<tr>
<td>0.26</td>
<td>Lysine (total)</td>
<td>0.82</td>
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<tr>
<td>3.9</td>
<td>Crude Fat</td>
<td>10.6</td>
</tr>
<tr>
<td>6.7</td>
<td>Neutral Detergent Fiber</td>
<td>35.1</td>
</tr>
<tr>
<td>0.20</td>
<td>Phosphorus</td>
<td>0.75</td>
</tr>
</tbody>
</table>
## Comparison of Dietary Fiber Methodology

**Campbell et al., 1997**

<table>
<thead>
<tr>
<th>Method</th>
<th>Beet pulp</th>
<th>Corn bran</th>
<th>Oat fiber</th>
<th>Soy polysaccharide</th>
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<tbody>
<tr>
<td>NDF (van Soest)</td>
<td>43.8</td>
<td>59.2</td>
<td>78.4</td>
<td>23.2</td>
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<tr>
<td>TDF (Prosky)</td>
<td>60.0</td>
<td>53.5</td>
<td>91.0</td>
<td>74.1</td>
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<tr>
<td>NSP (Englyst)</td>
<td>46.5</td>
<td>32.8</td>
<td>76.4</td>
<td>66.5</td>
</tr>
</tbody>
</table>
Beyond Fiber?

- Arabinose
- Rhamnose
- Galactose
- Glucose
- Xylose
- Mannose
- Fucose

Campbell et al., 1997/Sem. Food Anal. 2:43
Kim et al., 2008/Bioresource Technol. 99:5165

What is the degree of functional redundancy in microbes producing SCFA?
• E from SCFA to $NE_m$ ranges from 15 to 24% for gf pigs (Dierick et al., 1989; Yen et al., 1991; McBurney & Sauer, 1993)

• E from microbial fermentation accounts for 2.4 to 29.6% of total DE (Jensen, 2001)

• Available E as SCFA provides between 7.1 and 17.6% of the total available E (Anguita et al., 2006)
Renessen Is Developing A New Corn Processing System Increasing Refinery Yields And Co-Product Benefits

2008 UPDATE

THE RENESSEN CORN PROCESSING SYSTEM CAN BOLT ON TO A CONVENTIONAL DRY MILL PROCESS

STEP 1:
START WITH A NUTRITIONALLY DENSE CORN DEVELOPED THROUGH BIOTECH OR A CONVENTIONAL HYBRID

STEP 2:
PROCESS THE CORN THROUGH A NOVEL PROCESS TECHNOLOGY DEVELOPED BY CARGILL AND RENESSEN

STEP 3:
DELIVER FOUR HIGH VALUE REVENUE STREAMS
1: FOOD GRADE CORN OIL OR BIODIESEL
2: HIGH VALUE SWINE FEED
3: HIGHLY FERMENTABLE STARCH FOR ETHANOL PRODUCTION
4: HIGH PROTEIN, LOW OIL DDG

CONVENTIONAL DRY MILL PROCESS

NUTRIENT DENSE CORN → Elevator → Hammer Mill → Fermentation → Distillation → Ethanol

Drying

RENNESSEN FRACTIONATION AND EXTRACTION PROCESS

Fractionation

High oil fraction

Oil extraction

Nutrient-rich meal

Corn oil

HIGH OIL CORN FOR FOOD OR BIODIESEL

HIGH VALUE SWINE AND POULTRY FEED

HIGHLY FERMENTABLE FRACTION

HIGH PROTEIN LOW OIL DDG

Pilot plant has started up
HydroMilling overview

commodity corn

HydroMilling plant

High purity germ and fiber

Ethanol plant

starch/protein slurry

gluten solids and solubles

CO₂

ethanol

NeutraGerm

Germ to be processed for edible oil

WholeBran™

Food grade

ProBran™ PureBran™

Animal feed/Pet food

Glutenol™

Pet food/Aquaculture/Animal feed

Glutenol, WholeBran, ProBran, PureBran are trademarks of QTI, Inc. Elgin, IL
**Feed Ingredients**

In the feed industry, there are currently three primary Solaris brand names. Customized products can be created as the demand arises. Consistency in production and nutritional values are the keystones of the Solaris brand.

**Energia™** — With a higher protein level than DDGS, Energia is a low fat, high protein ingredient that is very palatable and extremely digestible. It can be used in higher concentrations by both ruminants and monogastrics. Energia is also low in phosphorus and low in potassium, and is a highly digestible source of critical nutrients.

**ProBran™** — A highly digestible source of NDF, ProBran is a very palatable, high fiber option. A great energy ingredient for ruminants. Low dust, ProBran is very flowable. This low fat product is great for creating additional value in your rations.

**Glutenol™** — This concentrated source of protein is high in energy, sulfur amino acids and available phosphorus. Unlike corn gluten meal, SO₂ is not added during the process, making Glutenol very palatable. Very low in moisture, it is also low dust and flowable, allowing it to mix easily. High cartenoids content creates a desirable gold color for eggs and poultry.

**Glutenol XP™** — With no solubles, XP is a more concentrated source of protein and amino acids.

**NeutraFiber™** — A pure fiber that is neutral in color, odorless, and bland in flavor. A consistent product, NeutraFiber is very concentrated in total dietary fiber (TDF).

**Food Ingredients**

Solaris custom corn products are a natural addition to the food industry. With a concern for trans fats and allergens, corn ingredients are the perfect source for stable vegetable oil, protein and fiber. With the exclusive SO₂-free HydroMilling process allowing for separation of the corn germ and bran, the possibilities for food applications are tremendous. Contact a QTI representative to learn more about food applications and Solaris products.

**Solaris**

The opportunity to create better food and feed products exists today from the burgeoning ethanol industry which utilizes corn to help lessen dependence on depleting oil sources. Quality Technology International is partnering with ethanol, food, feed and farming to market innovative technologies to advance these industries.

Solaris brands are on the forefront of creating higher-value, natural products that add to the appeal of ethanol production. A commitment to quality control assures products that are consistent time after time. To learn more about the Solaris brand of products, call your QTI representative or visit our website at www.solarisquality.com.
The Biodiesel Reaction

\[
\begin{align*}
\text{CH}_2\text{OCOR}'' & \quad + \quad 3 \text{ ROH} \quad \xrightarrow{\text{Catalyst}} \quad \text{CH}_2\text{OH} \quad \text{R}''\text{COOR} \\
\text{CH}_2\text{OCOR}' & \quad + \quad \text{Methanol} \quad \text{NaOH} \quad \text{KOH} \quad (\text{Na methylate}) \\
100 \text{ pounds} & \quad 10 \text{ pounds} \quad 10 \text{ pounds} \quad 100 \text{ pounds} \\
\text{Oil or Fat} & \quad \text{Alcohol (3)} \quad \text{Glycerin} \quad \text{Biodiesel (3)} \\

160^\circ\text{F for 1-8 hours}
\end{align*}
\]

Ethanol delivers 25% more energy than input E while biodiesel delivers 93% more energy than input E. (PNAS 103:11206-11210)
Corn Fractionation/Processing

A schematic of the modified ethanol process with germ and fiber recovery

Whole corn → Soak → Germ and Fiber Separation → Drying → Separation

- Germ
- Coarse Fiber

- DDGS
- Reduced oil DDGS
- Corn germ with or without oil
- DDG
- Solubles/stillage/liquor
- Corn bran with or without S
- HP-DDG
- Corn germ meal
- Corn gluten meal
- Corn gluten feed
- Corn oil
- Corn starch
- Dehulled degemmed corn

Whole corn → Soak → Germ and Fiber Separation → Drying → Separation

- Germ
- Coarse Fiber

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- Corn germ meal
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- Corn gluten feed
- Corn oil
- Corn starch
- Dehulled degemmed corn
### Bio-Refining Process Flow: Ingredient Origin

**Whole Corn**
- FF Germ
- Endosperm
- Dry Milling
- Corn Germ Dehydrated
- Dry
- Dakota Gold HP (Improved DDG)
- Neutral Detergent Fiber (Improved DDG)
- Syrup
- Dakota Bran Cake (Bran & Syrup)

*Feed Products in Red*

---

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>dCGM</th>
<th>DDGS</th>
<th>HP-DDG</th>
<th>Bran</th>
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<tr>
<td><strong>Corn</strong></td>
<td>9.3</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Crude Protein</td>
<td>16.3</td>
<td>29.8</td>
<td>43.2</td>
<td>14.6</td>
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<td>Lysine (total)</td>
<td>0.86</td>
<td>1.01</td>
<td>1.22</td>
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<tr>
<td>Crude Fat</td>
<td>17.3</td>
<td>11.5</td>
<td>3.9</td>
<td>9.8</td>
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<tr>
<td>Neutral Detergent Fiber</td>
<td>23.2</td>
<td>26.5</td>
<td>24.2</td>
<td>21.3</td>
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<tr>
<td>Phosphorus</td>
<td>1.49</td>
<td>0.92</td>
<td>0.48</td>
<td>0.65</td>
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</table>
### Evaluation of corn co-products in finishing pigs (preliminary data)¹

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<thead>
<tr>
<th>Ingredient</th>
<th>BW, kg</th>
<th>Basal</th>
<th>Test</th>
<th>ADFI, kg</th>
<th>Fecal output, g/d</th>
<th>Fecal digest, %²</th>
<th>DE²</th>
<th>ME²</th>
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<tr>
<td>Gluten feed</td>
<td>111.3</td>
<td>1712</td>
<td>800</td>
<td>1712</td>
<td>620</td>
<td>51.52</td>
<td>2517</td>
<td>2334</td>
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<tr>
<td>Bran (ICM)</td>
<td>111.4</td>
<td>1689</td>
<td>720</td>
<td>1689</td>
<td>521</td>
<td>55.99</td>
<td>3004</td>
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<tr>
<td>Bran (Poet)</td>
<td>111.4</td>
<td>1671</td>
<td>759</td>
<td>1671</td>
<td>466</td>
<td>63.66</td>
<td>3282</td>
<td>3031</td>
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<td>DDGS (ACE)</td>
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<td>1647</td>
<td>749</td>
<td>1647</td>
<td>371</td>
<td>80.50</td>
<td>4332</td>
<td>4141</td>
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<td>DDGS (MNdrum)</td>
<td>119.3</td>
<td>1525</td>
<td>660</td>
<td>1525</td>
<td>355</td>
<td>69.72</td>
<td>4116</td>
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<td>DDGS (MNmicro)</td>
<td>116.2</td>
<td>1532</td>
<td>652</td>
<td>1532</td>
<td>346</td>
<td>70.47</td>
<td>4016</td>
<td>3713</td>
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<td>DDGS (Hawk)</td>
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<td>1763</td>
<td>776</td>
<td>1763</td>
<td>458</td>
<td>69.19</td>
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<td>746</td>
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<td>66.16</td>
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<td>DDGS (VS)</td>
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<td>1762</td>
<td>403</td>
<td>75.04</td>
<td>4164</td>
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<td>RO-DDGS (VS)</td>
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<td>736</td>
<td>1728</td>
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<td>73.87</td>
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<td>Gluten meal</td>
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<td>702</td>
<td>1574</td>
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<td>90.71</td>
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<td>HP-DDG (ICM)</td>
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<td>1634</td>
<td>717</td>
<td>1634</td>
<td>369</td>
<td>75.00</td>
<td>3994</td>
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<td>HP-DDG (MOR)</td>
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<td>1570</td>
<td>702</td>
<td>1570</td>
<td>305</td>
<td>86.59</td>
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<td>HP-DDG (Poet)</td>
<td>106.8</td>
<td>1521</td>
<td>716</td>
<td>1521</td>
<td>315</td>
<td>81.00</td>
<td>4210</td>
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<td>DCG (Poet)</td>
<td>106.0</td>
<td>1630</td>
<td>739</td>
<td>1630</td>
<td>380</td>
<td>74.22</td>
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<td>3692</td>
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<td>Germ meal</td>
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<td>684</td>
<td>1574</td>
<td>387</td>
<td>74.57</td>
<td>3521</td>
<td>3417</td>
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<td>Solubles (20%)</td>
<td>111.9</td>
<td>1729</td>
<td>383</td>
<td>1729</td>
<td>269</td>
<td>75.49</td>
<td>4762</td>
<td>4525</td>
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<td>DH-DG corn</td>
<td>110.7</td>
<td>1692</td>
<td>720</td>
<td>1692</td>
<td>207</td>
<td>100.32</td>
<td>4401</td>
<td>4316</td>
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<tr>
<td>Starch</td>
<td>113.4</td>
<td>1603</td>
<td>717</td>
<td>1603</td>
<td>156</td>
<td>101.39</td>
<td>4082</td>
<td>4080</td>
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<td>Oil (10%)</td>
<td>117.3</td>
<td>2097</td>
<td>266</td>
<td>2097</td>
<td>232</td>
<td>97.22</td>
<td>8988</td>
<td>8755</td>
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</table>
## Comparative ME values, kcal/kg DM

<table>
<thead>
<tr>
<th></th>
<th>Corn</th>
<th>Starch</th>
<th>Oil</th>
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<tbody>
<tr>
<td>Anderson</td>
<td>3771</td>
<td>4080</td>
<td>8755</td>
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<tr>
<td>NRC</td>
<td>3843</td>
<td>4025</td>
<td>8405</td>
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<tr>
<td>Moeser 2002</td>
<td>3788</td>
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<tr>
<td>Pedersen 2007</td>
<td>3989</td>
<td></td>
<td></td>
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<tr>
<td>Widmer 2007</td>
<td>3972</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Variation in ME content of DDGS

Corn = P3989 A3771 (3830 Spiehs)

ME, kcal/kg DM

DDGS Sample

P1 P2 P3 P4 P5 P6 P7 P8 P9 P10 A1 A2 A3 A4 A5 A6

3897

3798
Prediction of DE, ME, or NE from Feed Components

- Drennan & Maguire, 1970 (DE)
- Harris et al., 1972 (ME)
- Morgan et al., 1975 (DE, ME)
- King & Taverner, 1975 (ME)
- Henry, 1976 (DE)
- Kirchgessner & Schneider, 1978 (NE\text{fat})
- Batterham et al., 1980 (DE)
- Jorgensen, 1980 (ME)
- Perez et al., 1980 (DE)
- Wiseman & Cole, 1979 (DE, ME)
- Eeckhout & Moermans, 1981 (DE, ME, NE\text{growth})
- Kirchgessner & Roth, 1981 (ME)
- Wenk, 1982 (DE)
- Just et al., 1984 (DE, ME, NE)
- Noblet & Perez, 1993 (DE, ME)
- Noblet et al., 1994 (DE, ME, NE)
- Adedokun & Adeola, 2005 (ME for M&B)
- Pederson et al., 2007 (DE, ME)
Nutrients to analyze, but note there is variation in determination of components within a feedstuff!

- DM
- GE
- CP
- Starch
- EE
- Ash
- CF
- NDF
- ADF
- ADL
Factors Affecting Energy Utilization

- \( \text{DE}_{28} = 1,161 + (0.749 \times \text{GE}) - (4.3 \times \text{Ash}) - (4.1 \times \text{NDF}) \)

- \( \text{ME}_{45} = (0.997 \times \text{DE}) - (0.68 \times \text{CP}) + (0.23 \times \text{EE}) \)
  - \( \text{ME}/\text{DE} \times 100 = 99.7 - (0.18 \times \%\text{CP}) \) Morgan et al., 1975

- \( \text{NE}_8 = (0.726 \times \text{ME}) + (1.33 \times \text{EE}) + (0.39 \times \text{ST}) - (0.62 \times \text{CP}) - (0.83 \times \text{ADF}) \)

Noblet & Perez, 1993/JAS 71:3389
Noblet et al., 1994/JAS 72:344
Prediction of ME (Anderson data)

\[ ME = -11,128 - (124.99 \times \text{ash}) + (35.76 \times \text{CP}) - (63.40 \times \text{EE}) - (150.92 \times \text{ADF}) + (14.85 \times \text{NDF}) + (3.023 \times \text{GE}) \]

[Pedersen et al., 2007/JAS 85:1168]

\[ ME = 4,194 - (9.2 \times \text{ash}) + (1.0 \times \text{CP}) + (4.1 \times \text{EE}) - (3.5 \times \text{NDF}) \]

[Noblet & Perez, 1993/JAS 71:3389]
ME of high protein corn co-products

<table>
<thead>
<tr>
<th></th>
<th>Corn</th>
<th>Corn gluten meal</th>
<th>HP-DDG (ICM)</th>
<th>HP-DDG (MOR)</th>
<th>HP-DDG (POET)</th>
<th>Corn (Pedersen)</th>
<th>HP-DDG (POET) (Pedersen)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ME, kcal/kg DM</td>
<td>3500</td>
<td>3700</td>
<td>3900</td>
<td>4100</td>
<td>4300</td>
<td>4500</td>
<td>4700</td>
</tr>
</tbody>
</table>
ME of reduced oil corn co-products

ME, kcal/kg DM

Corn germ meal
DCG (Poet)
DDGS (VeraSun)
RO-DDGS (VeraSun)
RO-DDGS (VeraSun) (Jacela)
ME of high and low fiber corn co-products

<table>
<thead>
<tr>
<th>Product</th>
<th>ME, kcal/kg DM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>3800</td>
</tr>
<tr>
<td>Corn gluten feed</td>
<td>2400</td>
</tr>
<tr>
<td>Corn bran (ICM)</td>
<td>3000</td>
</tr>
<tr>
<td>Corn bran (POET)</td>
<td>3200</td>
</tr>
<tr>
<td>Dried solubles</td>
<td>4600</td>
</tr>
<tr>
<td>DHDG Corn</td>
<td>4400</td>
</tr>
</tbody>
</table>
Fiber in Swine Diets

- **Increase endogenous protein loss**
  - Increased mucin production (affects threonine nutrition)

- **Decrease absorption of proteins and lipids**
  - Decrease urinary urea excretion (increased fecal N excretion)
  - Lipid metabolism and meat quality…

- **Increase in intestinal mass (in some cases)**
  - Maintenance requirements increase
  - Initial increase, may not be noted long term trial

- **Increased heat increment (increased energy loss)**

- **Feed intake**
  - Variable effects (+ or -)

- **Dealing with fiber in swine diets**
  - Feed low levels
  - Enzymes
  - Processing
  - Genetics…
Concerns with Co-Products

- Alternative feedstuffs.
  - EtOH co-product variation
  - Left with corn fiber and protein
    - Energy removed for ethanol AND?
  - Fat fraction remains for now!
    - Removal of oil for biodiesel production is currently underway!

- Carcass quality concerns.
  - Fat quality / Lipid composition.
  - Pork nutritional value?
  - Carcass yield.
  - Oil content may soon be going down due to removal of oil for biodiesel!

- Positive impacts on whole animal and/or intestinal health?
  - Inflammation.
  - Ileitis severity.

- Mycotoxin concentration?

- Handling characteristics.
Feeding fermentable fibers will increase VFA concentrations in feces and manure and thereby reduce manure pH and ammonia emissions.

Chan et al., 1998/JAS 76: 1123 & 1187

Manure DM output increase!

CSBM = 302 g/d

DDGS 30% = 430 g/d (+42%)

Corn bran 30% = 521 g/d (+73%)
The research goal is to develop practical technologies resulting in improved gastrointestinal and whole-animal nutrient utilization and a modified microbial ecology (including pathogens) leading to a reduction of the impact of livestock production on the soil, water, and air environment.