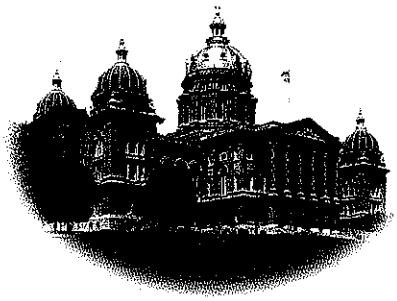

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September 13, 2007

TO: CO-CHAIRPERSONS SENATOR RICH OLIVE AND REPRESENTATIVE JOHN WHITAKER, MEMBERS OF THE ANIMAL FEEDING OF DISTILLERS DRIED GRAINS STUDY COMMITTEE

FROM: DOUG ADKISSON, SENIOR LEGAL COUNSEL, LEGAL DIVISION, LEGISLATIVE SERVICES AGENCY

RE: BACKGROUND INFORMATION FOR ANIMAL FEEDING OF DISTILLERS DRIED GRAINS STUDY COMMITTEE

I. INTRODUCTION

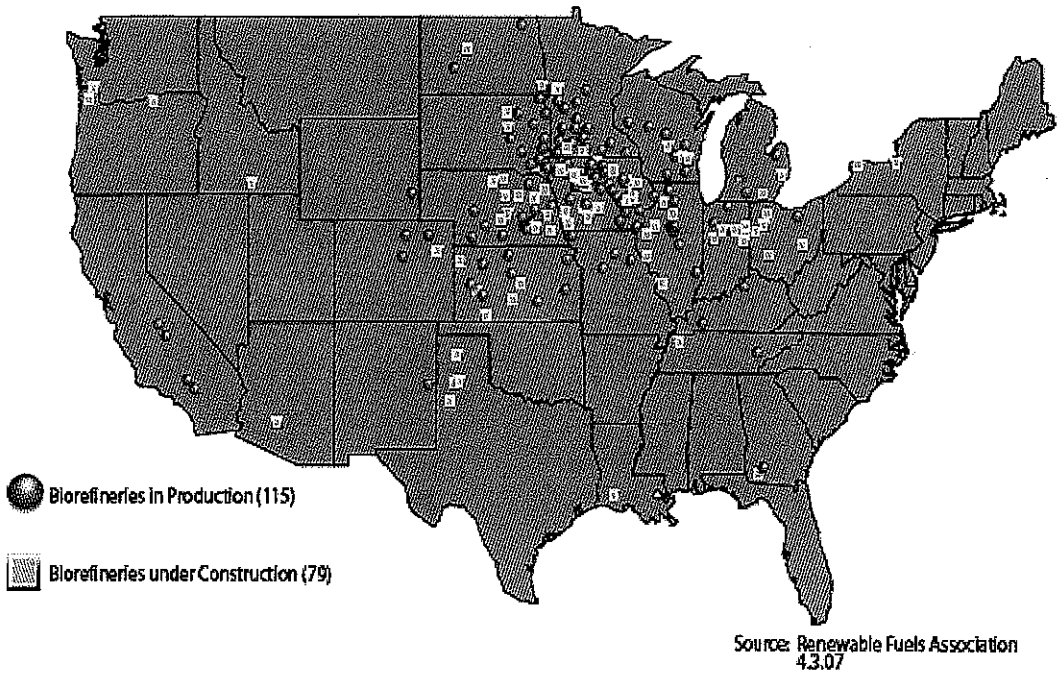
This background memorandum provides an overview of methods used by dry grinding milling operations to process starch-based feedstocks (corn) into ethanol and distilled coproducts, and principally addresses dry grinding operations. It discusses all major forms of distilled coproducts used for livestock feed, and especially distillers dried grain with solubles (DDGS) fed to beef and dairy cattle.

II. ETHANOL PRODUCTION

A. GENERAL. In 2006 production of ethanol equaled 4.86 billion gallons, an average of 317,000 barrels per day or 13.3 million gallons per day, and representing an increase of 24.3 percent above 2005 production levels.[1] In recent years the Midwest and especially Iowa has experienced a dramatic increase in the construction of biorefineries producing ethanol, overwhelmingly using corn as a feedstock.

[1] Renewable Fuels Association, RFA Press Releases, *2006 Ethanol Production Up Nearly 25 % Over 2005.* http://www.ethanolrfa.org/media/press/rfa/view.php?id=964.

UNITED STATES ETHANOL BIOREFINERY LOCATIONS[2]



B. CORN AS THE PRIMARY FEEDSTOCK. Corn is the primary grain used in milling operations, because of its high fermentable starch content compared to other feedstocks. In addition, nonstarch components are a rich source of nutrients for livestock.

Components of Yellow Dent Corn[3]

Starch	61.0 percent
Corn Oil	3.8 percent
Protein	8.0 percent
Fiber	11.2 percent
Moisture	16.0 percent

C. MILLING OPERATIONS. For purposes of producing ethanol, corn is processed by one of two manufacturing methods: wet milling or dry grinding.[4] Wet mills are more expensive to construct, but produce a wider range of products including ethanol and livestock feed. Wet milling initially accounted for

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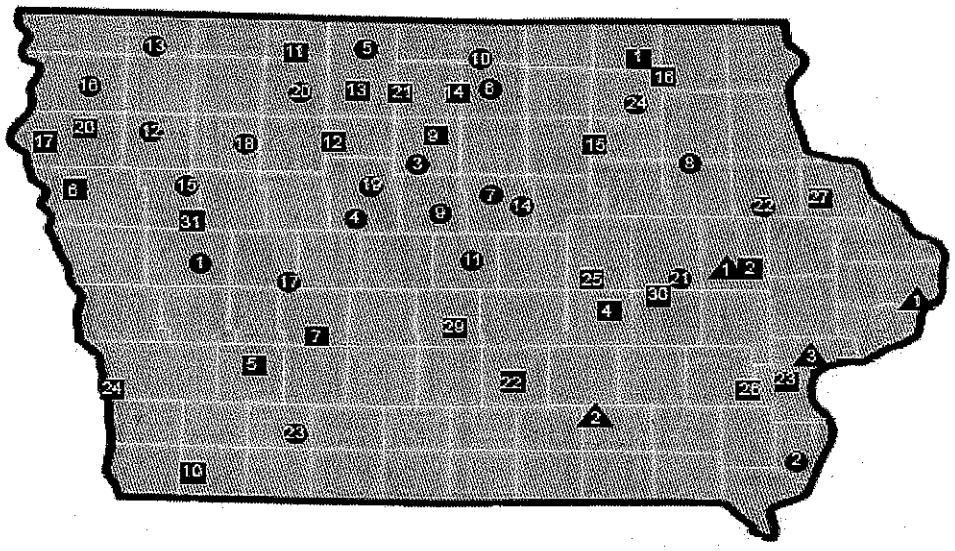
[2] Renewable Fuels Association Website: http://www.ethanolrfa.org/objects/documents/plantmap_040307.pdf.

[3] Kelly S. Davis, Quality Manager Chippewa Ethanol Co., *Corn Milling, Processing and Generation of Co-products,* Minnesota Nutrition Conference, Technical Symposium, September 11, 2001. http://www.distillersgrains.org/files/grains/K.Davis--Dry&WetMillProcessing.pdf.

[4] The term "dry milling" is sometimes used to describe this process, but is technically a distinct type of processing operation in which fat contained in the germ is separated from the endosperm. Dry milling's premium product is flaking grits used primarily in breakfast cereals. See Kent D. Rausch, Assistant Professor, Agricultural and Biological Engineering, University of Illinois, and Ronald L. Belyea, Professor Animal Sciences, University of Missouri, *Coproducts from Bioprocessing of Corn* (Paper Number: 057041), p. 4-7, ASAE Meeting Presentation, July 17-20, 2005. http://www.ddgs.umn.edu/articles-proc-storage-quality/2005-Rausch-%20Coproducts %20from%20bioprocessing--.pdf.

most of the ethanol fuel production in the United States, but new construction has shifted to dry grinding, presumably because of lower construction costs and somewhat greater ethanol production; a new dry grinding mill can produce 2.8 gallons per bushel, compared with about 2.7 gallons for a wet milling operation.[5] As of January 2007, dry grinding operations accounted for 82 percent of ethanol production and wet milling operations only 18 percent.[6]

MILLING OPERATIONS IN IOWA[7]



Dry Mills- Production

1 Denison-Amaizing Energy
2 West Burlington-Big River Resources
3 Goldfield-Corn, LP
4 Gowrie-Frontier Ethanol LLC
5 Lakota-Global Ethanol
6 Mason City-Golden Grain Energy LLC
7 Iowa Falls-Hawkeye Renewable LLC
8 Fairbank-Hawkeye Renewables LLC
9 Jewell-Horizon Ethanol
10 Hanlontown-Iowa Ethanol LLC
11 Nevada-Lincolnway Energy
12 Marcus-Little Sioux Corn Processors
13 Ashton-Otter Creek Ethanol LLC
14 Steamboat Rock-Pine Lake Corn Processors LLC
15 Galva-Quad-County Corn Processors
16 Sioux Center-Siouxland Energy and Livestock LLC
17 Coon Rapids-Tall Corn Ethanol
18 Albert City-US BioEnergy
19 Fort Dodge-VeraSun
20 Emmetsburg-Voyager Ethanol
21 Blairstown-Xethanol BioFuels, LLC
22 Hopkinton-Xethanol BioFuels, LLC
23 Corning- Pinnacle Ethanol, LLC
24 Charles City- VeraSun

Wet Mills

1 Clinton & Cedar Rapids-ADM
2 Eddyville-Cargill
3 Muscatine-Grain Processing Corp.

Dry Mills-Under Construction/Planning

1 St. Ansgar-Absolute Energy, LLC
2 Cedar Rapids-ADM
3 Ogden -Alternative Energy Sources
4 Grinnell-Big River Resources
5 Atlantic-Cass Co Amaizing Energy
6 Marcus- Little Sioux Corn Processors
7 Dexter-Dexter Ethanol
8 Grand Junction -Further Fuels
9 Belmond-Global Ethanol
10 Shenandoah-Green Plains Renewable Energy
11 Superior-Green Plains Renewable Energy
12 Gilmore City -Harvest Biofules LLC
13 Galbraith-Harvest Biofules LLC
14 Garner-Harvest Biofules LLC
15 Shell Rock -Hawkeye Renewables LLC
16 New Hampton-Hometown Energy Solutions
17 Akron-Little Sioux Corn Processors
18 Arthur -Platinum Ethanol, LLC
19 Merrill-Plymouth Energy, LLC
20 Wesley -Prarie Creek Ethanol
21 Pleasantville -Red Rock Renewables
22 Buffalo-River/Gulf Energy
24 Council Bluffs-Southwest Iowa Renewable Energy
25 Tama-Tama Ethanol LLC
26 Washington -TerraEnergies, LLC
27 Dyersville-US BioEnergy
28 Des Moines-Vision Fuels LLC
29 Blairstown- Xenthanol BioFuels, LLC
30 Arthur- Platinum Ethanol LLC

[5] C. Matthew Rendleman and Hosein Shapouri, Office of Energy Policy and New Uses, United States Department of Agriculture *New Technologies in Ethanol Production* (AER-842), p. 6. February 2000 http://www.usda.gov/oce/energy/aer842_ethanol.pdf.

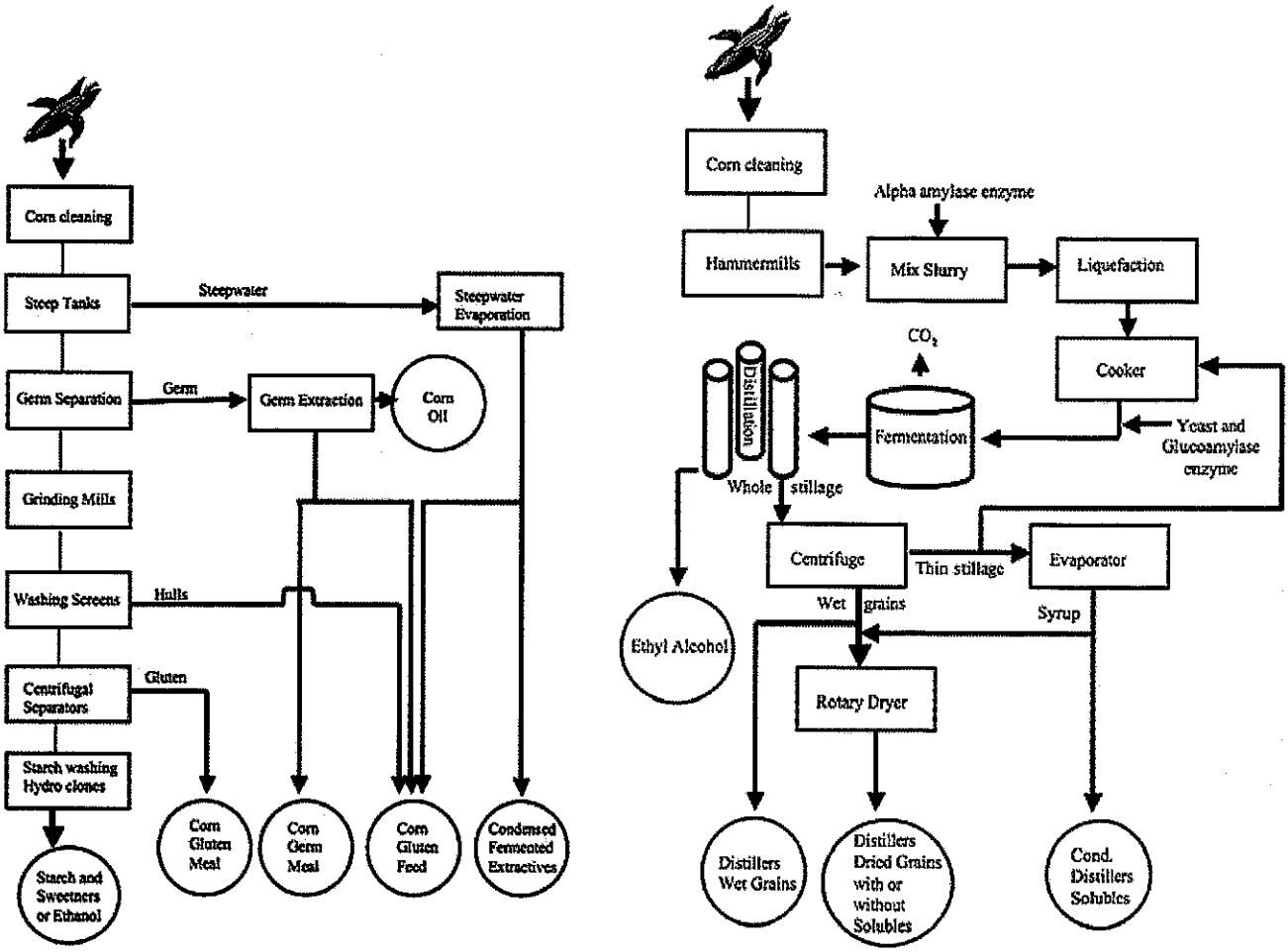
[6] Renewable Fuels Association, *How Ethanol is Made.* http://www.ethanolrfa.org/resource/made/

[7] Iowa Corn Growers Association Website, *Iowa Ethanol Plants,* July 16, 2007. http://www.iowacorn.org/ethanol/documents/EthanolMapfortheWebonly4-07.pdf.

II. TYPES OF MILLING OPERATIONS

The two primary types of milling processes produce different feed products. The wet milling process produces corn gluten feed and the dry grinding process produces distillers grains plus solubles, with both feeds marketed as wet (or modified wet) or dry.

WET MILLING COMPARED WITH DRY GRINDING (PRODUCTION OF LIVESTOCK FEED) [8]



A. Wet Milling. In a wet milling operation, corn is steeped for separation into different components and then the components are further processed to produce various coproducts derived from: (1) Cleaning the corn, (2) Grinding and screening the corn [to produce corn oil and fiber for livestock feed], and (3) Further separating gluten from starch including gluten meal for livestock feed, and ethanol, biochemicals, and high fructose corn syrup.

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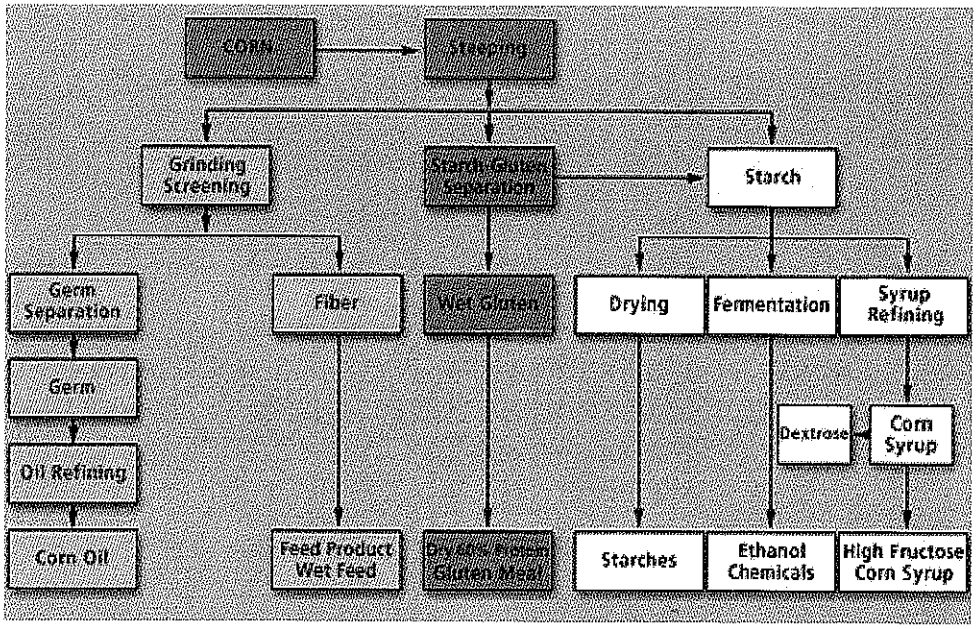
[8] Todd Applegate and Brian Richert, Department of Animal Sciences and Dirk Maier, Department of Agricultural and Biological Engineering, Purdue University, *Feed Ingredient Co-products of Ethanol Fermentation from Corn* (ID-333), p. 2-3. December 2006. http://www.ces.purdue.edu/extmedia/ID/ID-333.pdf.

WET MILLING[9]



The contents of the different component streams segregated during corn oil production and the segregation of starch and gluten may be recombined and processed to produce specific rations. Livestock feed associated with wet milling includes:

- **Condensed corn fermented extractives** (or corn steep liquor), a high-energy liquid feed ingredient.

- **Corn germ meal** having 20 percent protein, 2 percent fat, and 9.5 percent fiber, and used to feed poultry and swine.

- **Corn gluten feed,** a medium protein ingredient composed of the bran and fibrous portions which is marketed wet or dry, having 21 percent protein, 2.5 percent fat, and 8 percent fiber.

- **Corn gluten meal**, a high protein concentrate typically supplied at 60 percent protein, 2.5 percent fat, and 1 percent fiber which is used in poultry feed formulators and in cattle feed for its high level of rumen bypass protein.[10]

B. Dry Grinding. In a dry grinding operation, corn is produced for ethanol and all remaining nutrients (protein, fat, minerals, and vitamins) are concentrated into distillers grain, available for use as livestock feed.

1. **The Process.** In dry grinding, the entire corn kernel is ground (hammer milled) into meal without separating its components. This meal is mixed with ratios of fresh and recycled waters to form a slurry. The pH and temperature levels are adjusted and an alpha amylase enzyme is added to the mash which converts starch to dextrin (long chain sugars) in a process referred to as liquefaction. The mash is heated ("cooked") to kill lactic acid which would otherwise produce contaminating bacteria. The mash is cooled and subjected to fermentation. A glucoamylase enzyme is added that converts the dextrin into the simple sugar dextrose. A yeast species

[9] Renewable Fuel Association, *How Ethanol is Made*, supra at p. 2.
[10] Davis, *Corn Milling, Processing and Generation of Coproducts,* supra.

(saccharomyces cerevisiae) is added to metabolically convert the dextrose into ethanol and carbon dioxide. The result is "beer" (fermented mash that contains ethanol). The beer is distilled to separate ethanol from whole stillage from the bottom of the distillation tanks contains solids from the grain and added yeast as well as liquid from the water added during the process, and is comprised of approximately 15 percent solids (including fiber, protein, and fat). The primary market materials for most dry grind processing plants are ethanol and distillers grain usually marketed as distillers dried grains with solubles. A few processing plants capture and market the carbon dioxide produced from the fermentation stage.

2. **Livestock Feed.** After distillation and the removal of ethanol from the yeast fermented corn, the remaining wet material (whole silage) is subjected to centrifugation which separates it into two fractions: (1) thin stillage and (2) coarse solids.

   a. **Thin Stillage** which is a liquid fraction containing small particles of grain, yeast, and soluble nutrients.[11] Some thin stillage is routed back to the cook/slurry process as makeup water, reducing the amount of fresh water required during the initial stages of processing. The majority of thin stillage is subject to an evaporation system where it is concentrated into syrup.[12]

   b. **Coarse Solids** which are the coarse, unfermented grains.

The two fractions are rich in cereal proteins, fat (energy), minerals, and vitamins. Each fraction may be marketed "as is", but typically is further processed (dried, concentrated, and often recombined) before being marketed as livestock feed. Coproducts produced from each processing stream are distinguished based on a measure of dry matter versus moisture content. Generally the lower the dry matter content, and inversely the higher the moisture content, the less convenient and the more expensive the coproduct is to store and transport. Alternatively, increasing the coproduct's dry matter content decreases storage and transportation costs, but increases energy costs. Consequently, wet coproducts tend to be marketed to local livestock producers who purchase them at a rate less than coproducts with a higher dry matter to moisture content. Persons who have livestock operations in proximity to a dry grinding operation enjoy a competitive advantage when purchasing distillers grains because they may purchase the wet form and avoid drying and transportation costs.

c. **Thin Stillage Coproducts.** Generally, only one coproduct is processed from the thin stillage fraction, referred to as condensed distillers solubles (CDS). It is manufactured by condensing the thin stillage into semisolid "syrup" during a process of partial evaporation creating a coproduct with a dry matter content within a range of 23-45 percent.[13] Note, CDS may be further dried to produce distillers dried solubles (DDS),[14] a relatively rare feed supplement, but is usually combined with a coproduct derived from the processing of coarse solids, either distillers wet grains (DWG) or distillers modified wet grains (DMWG) or more frequently distillers dried grains (DDG).

d. **Coarse Solids Coproducts.** From coarse solids three coproducts may be produced, that are again distinguished by their dry matter to moisture content. After centrifugation and the

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[11] J.W. Schroeder, Extension Dairy Specialist, North Dakota State University Extension Service, *Distillers Grains for Dairy Cattle as a Protein and Energy Supplement*, (AS-1241), p. 2. February 2003. http://www.ddgs.umn.edu/articles-dairy/2003-Schroeder-%20Distillers%20grains%20as%20a%20protein%20and--.pdf.

[12] U.S. Grains Council, *DDGS Handbook DDGS Glossary of Terms,* p. 2. http://www.grains.org/galleries/DDGS%20Use %20Handbook/14%20-%20DDGS%20Glossary.pdf.

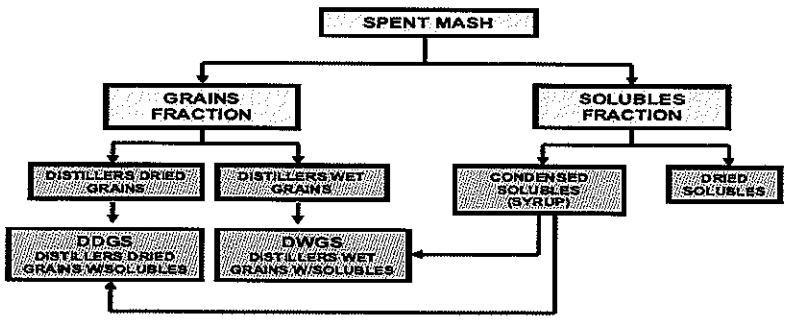
[13] Greg Lardy, Extension Beef Cattle Specialist, Department of Animal and Range Sciences, North Dakota State University, *Feeding Coproducts of the Ethanol Industry to Beef Cattle* (AS-1242), April 2003. http://www.ag.ndsu.edu/pubs/ansci/beef/as1242w.htm.

[14] Daniel D. Loy, Professor of Animal Science, Iowa State University Extension, Iowa State University, and Ms. Wendy Miller, Communications Specialist, Iowa Beef Center, Iowa State University, "Wet Distillers Feeds for Feedlot Cattle" in *Ethanol Coproducts for Cattle,* (IBC-19), August 2002. http://www.extension.iastate.edu/Publications/IBC19.pdf.

removal of thin stillage, the solids remaining are wet distillers grains (WDG), sometimes referred to as "wetcake" containing approximately 30 percent dry matter (with a "shelf life" of up to seven days during summer conditions).[15] The WDG is usually marketed locally (within 50 miles of the dry grinding operation) to reduce the risk of spoilage especially in summer months.[16] The WDG may be semidried or combined with a dried form of WDG to produce distillers modified wet grains (DMWG), containing an intermediate level of moisture with approximately 50 percent dry matter content. It therefore has greater longevity than WDG, depending upon ambient temperature and management practices, and decreases problems otherwise associated with distillers wet grains (with a shelf life of approximately 10 days). Finally WDG may be fully dried to produce distillers dried grains (DDG) containing approximately 90 percent dry matter (with an indefinite shelf life), regardless of whether solubles are added.[17]

e. **Blended Coproducts.** The CDS derived from the thin stillage fraction may be blended with all coarse solids coproducts, on a wet, semidried, or dried basis. When combined with wet distillers grain the result is distillers wet grains with solubles (DWGS) and when combined with distillers modified wet grains the result is DMWG. Finally when combined with distillers dried grains, the result is distillers dried grains with solubles (DDGS). The dry matter content and corresponding longevity of a coarse solids coproduct WDG, DMWG, or DDG is not affected by the addition of solubles.

PRODUCTION OF LIVESTOCK FEED FROM DRY GRINDING OPERATIONS[18]



The following definitions for livestock feed derived from distillers grains have been developed by the Association of American Feed Control Officials:

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[15] Lardy, *Feeding Coproducts of the Ethanol Industry to Beef Cattle*, supra.

[16] Connie L. Hardy and Mary S. Holz-Clause, Value Added Agriculture Program, Iowa State University Extension, and Howard E. Shepherd and Charles R. Hurburgh, Iowa Grain Quality Initiative, *Sourcing Corn for Ethanol Impacts of Local Processing, A Project of the Iowa Grain Quality Initiative*, November 2006, p. 9, citing Ives, *Boundless Potential: Exploring the Future of Distillers Grains*, International Distillers Grains Conference, 2006, Minneapolis, MN. http://www.extension.iastate.edu/NR/rdonlyres/CA82517C-452B-4FAB-998B-5422F90042F2/45824/finalreportsourcingcornethanol06.pdf.

[17] Lardy, *Feeding Coproducts of the Ethanol Industry to Beef Cattle*, supra.

[18] National Corn Growers Association, *Distillers Grains Feeding Recommendations, for Beef, Dairy, Swine, and Poultry*, May 19, 2004. http://www.ncga.com/ethanol/pdfs/111005DGFeedingRecommendations.pdf.

ASSOCIATION OF AMERICAN FEED CONTROL OFFICIALS (AAFCO) FEED INGREDIENT DEFINITIONS[19]

Corn Distillers Dried Grains (DDG) is obtained after the removal of ethyl alcohol by distillation from the yeast fermentation of corn by separating the resultant coarse grain fraction of the whole stillage and drying it. (27.5)

Corn Distillers Dried Grains with Solubles (DDGS) is obtained after the removal of ethyl alcohol by distillation from the yeast fermentation of corn by condensing and drying at least three=quarters of the solids of the resultant whole stillage. (27.6)

Corn Distillers Wet Grains (DWG) is the product obtained after the removal of ethyl alcohol by distillation from the yeast fermentation of corn. (27.8)

Corn Condensed Distillers Solubles (CDS) is obtained after the removal of ethyl alcohol by distillation from the yeast fermentation of corn by condensing the thin stillage fraction to a semisolid. (27.7)

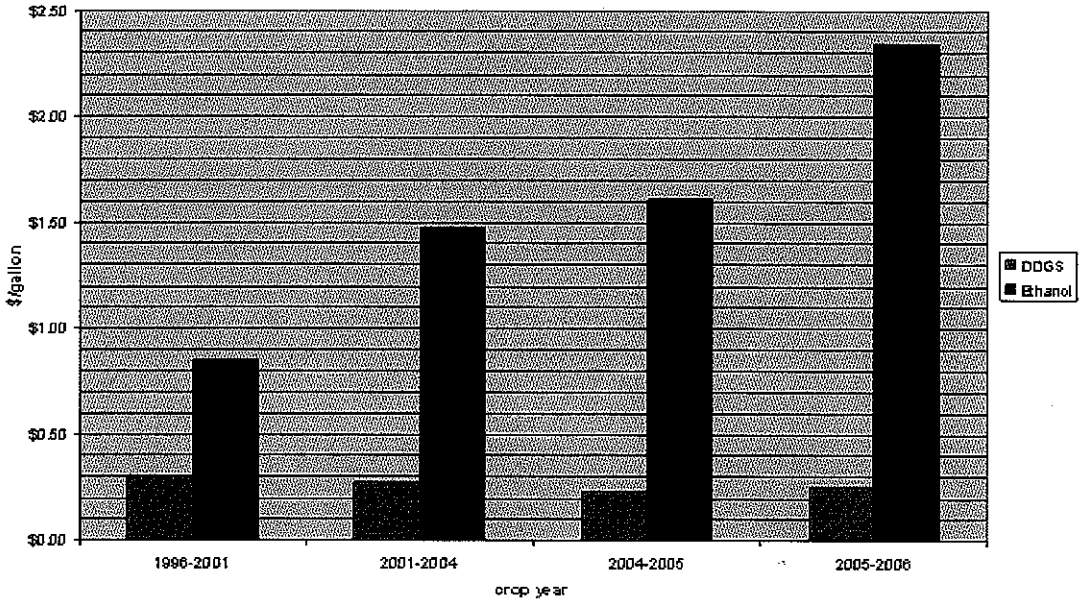
NOTE: Official AAFCO definitions do not exist for Distillers Wet Grains with Solubles (DWGS) and the variety of "modified" distillers grains products currently on the market.

III. MARKETING DISTILLERS GRAINS FROM DRY GRINDING OPERATIONS

A. METHODS OF MARKETING. In 2006, of all revenues earned by dry grinding operations, 5 percent were from sales of distillers grains.[20] A dry grinding operation sells distillers grains directly through an in-house merchandiser or an independent broker.[21] The predominate marketing method is on the spot market, although long-term contracts (3-12 months) may be becoming more common among beef cattle and dairy cattle customers.[22] There is some evidence that swine producers are more likely to purchase feed on a short-tem (weekly) basis, but may be moving toward longer-term contracts.[23]

[19] National Corn Growers Association, *Distillers Grains Feeding Recommendations, for Beef, Dairy, Swine, and Poultry,* supra.
[20] Hardy, Holz-Clause, Shepherd, and Hurburgh, *Sourcing Corn for Ethanol: Impacts of Local Processing,* supra at p. 8.
[21] Id.
[22] Id.
[23] Id.

REVENUE FROM SALES OF ETHANOL AND DDGS[24]



B. TYPES OF COPRODUCTS MARKETED. In 2006, dry grinding operations in Iowa sold 25 percent of their distillers grains in a wet form or modified wet form (within a range of 50-65 percent moisture) and 75 percent in a dried form (within a range 9-13 percent moisture).[25] In all cases, the price for distillers grain is related to the price of corn.

1. **The Wet or Modified Wet Form.** Dry grinding operations utilize limited space for storing the wet or modified wet form (an average of 5.1 days of production) because of its limited longevity.[26] Mycotoxin-producing fungi (*Aspergillus flavus* and *Fusarium*) affect the form, especially when exposed to oxygen, thus presenting a risk for fumonisin and aflatoxin production.[27] During the summer, with high temperature and humidity levels, the wet form tends to mold within seven days and at a longer rate during the winter (not to exceed three to four months unless extra precautions are taken to limit exposure to oxygen, such as using plastic silage bags).[28] As previously noted, the wet or modified wet form is usually shipped by truck within a 50-mile radius of the milling operation.[29] In addition, larger Iowa feedlots tend to use the wet or modified wet form as compared to the cow-calf operations and smaller feedlots which are not as likely to have installed efficient feeding systems.[30] During the colder winter months,

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[24] Ryan Sauer, *Distillers Manager Hawkeye Renewables, Purchasing and Managing Distillers Grain*, p. 7. http://www.iowarfa.org/documents/Sauerpresentation-DG.ppt#988,2,What are distillers grains?.

[25] Hardy, Holz-Clause, Shepherd, and Hurburgh, *Sourcing Corn for Ethanol: Impacts of Local Processing,* supra at p. 0.

[26] Hardy, Holz-Clause, Shepherd, and Hurburgh, *Sourcing Corn for Ethanol: Impacts of Local Processing* , supra at p. 9.

[27] Gary Munkvold, Department of Plant Pathology, Iowa State University, "Potential Mold Related Problems In Ethanol Coproducts" in *Ethanol Feeds*, p. 2. July 2007. http://www.iowabeefcenter.org/content/2007/distillers%20newsletters/Distillers%20Newsletter%20July%20Final.pdf.

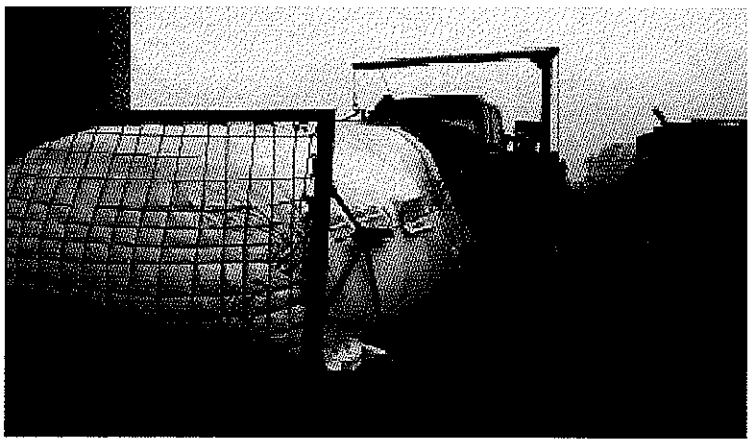
[28] Lardy, *Feeding Coproducts of the Ethanol Industry to Beef Cattle*, supra.

[29] Hardy, Holz-Clause, Shepherd, and Hurburgh, *Sourcing Corn for Ethanol: Impacts of Local Processing*, supra at p. 9.

[30] Daniel D. Loy, Professor of Animal Science, Iowa State University Extension, Iowa State University, and Daryl Strohbehn, Professor of Animal Science, Iowa State University Extension, "Long Term Storage of Wet Distillers Grains and CDS" in *Ethanol Feeds.* p. 1, July 2007. http://www.iowabeefcenter.org/content/2007/distillers%20newsletters/Distillers%20Newsletter%20July%20Final.pdf.

spoilage develops at a much slower rate, extending the storage time. However, storage should not exceed three to four weeks unless some form of preservatives are added to the feed or the feed is contained in plastic silage bags or other oxygen limiting structures are used to limit spoilage.[31] Research indicates that modified wet distillers grains may be stored in bags for a period of between 60 and 200 days and fed successfully to beef cattle.[32]

EXAMPLE OF PLASTIC SILAGE BAG STORING MODIFIED WET FORM[33]



2. The Dry Form. Alternatively, the dried form may be stored in conventional grain storage structures or in flat storage (e.g., a quonset).[34] Research indicates that the dry form has low levels of *Aspergillus flavus* present and shows no visible growth.[35] On average, dry grinding operations have enough capacity to dry at least 80 percent of the distillers grains they produce. However, there are two serious costs: (1) energy used for drying and (2) transportation for delivery to customers who do not feed livestock in proximity to a dry grinding operation. Most dry grinding operations utilize natural gas in order to dry distillers grain. It is estimated that 35-40 percent of a dry grinding operation's energy costs are associated with drying.[36] Almost 60 percent of distillers dried grains (with or without solubles) is shipped out of state usually by rail to feedlots and dairies in Western states (Nebraska, Oklahoma, Texas, Arizona, and California) and Mexico.[37]

IV. DIETARY ISSUES

A. GENERAL. Distillers grains such as gluten feed are low in starch and may be used as an effective supplement when used with other feedstuffs, especially poor quality forages. Since corn is comprised of approximately two-thirds starch, after completion of the fermentation process and the extraction of ethanol (and CO^2), the remaining distillers grains are a concentrated nutrient. In addition to protein, distiller's grains contain highly digestible fiber and fat (producing a higher energy value than corn).

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[31] Lardy, *Feeding Coproducts of the Ethanol Industry to Beef Cattle*, supra.
[32] Loy and Strohbehn, "Long Term Storage of Wet Distillers Grains and CDS", supra.
[33] Id.
[34] Lardy, *Feeding Coproducts of the Ethanol Industry to Beef Cattle*, supra.
[35] Munkvold, "Potential Mold Related Problems in Ethanol Coproducts", supra.
[36] Hardy, Holz-Clause, Shepherd, and Hurburgh, *Sourcing Corn for Ethanol Impacts of Local Processing A Project of the Iowa Grain Quality Initiative,* supra at p. 9.
[37] Id.

B. COMPOSITION. Generally, all of the components in dry corn, other than starch, are present in distilled grains, but at three times ordinary levels.[38] Distillers grains are considered a good protein source for beef and dairy cattle, because they are high in ruminally undegradable protein (RUP) and are also considered a good energy source for both growing cattle and lactating cows.[39] Indeed, distilled grains contain approximately 30 percent protein compared to approximately 20 percent protein in corn gluten feed (measured on a dry matter basis).[40]

Nutrient Value of Co-products From Wet Milling and Dry Grinding Operations[41]

Table 1.	Dry Corn Gluten Feed	Corn Gluten Meal	Wet Corn Gluten Feed	Condensed Steep Water Solubles
Dry Matter	90	90	42 - 44	50
Protein	20	66	17 - 21	35
Fat	2.8	2.2	3 - 4	3
Fiber	11.1	3.3	3.5	--
ADF	37.6	14	12 - 14	6 - 1
NDF	12.4	5	38.48	1.5
TDN	80	86	80	91
NEm	0.96	1	0.9 - 0.97	1
NEg	0.59	0.69	0.62 - 0.67	.72
Ca	0.055	0.08	0.03 - 0.1	0.07
P	1.1	0.53	0.5 - 1	2
K	1.6	0.22	1	3
Mg	0.5	0.088	0.3	0.9
Na	0.16	0.066	0.1	0.4 - 0.5
S	0.33	0.72	0.4 - 0.5	1.8 - 2
Fe	178	313	80 - 110	127 - 178
Cu	5.5	27	5 - 7	8
Zn	83.3	34	46 - 64	113 - 164
Mn	23.3	7.8	0.3	42 - 50

[38] Shawn S. Donkin, Timothy R. Johnson, and Mike M. Schutz, Department of Animal Sciences, Purdue University, *Value of Distillers' Grains for Lactating Dairy Cows,* (ID-334-W), December 2006. http://www.ces.purdue.edu/extmedia/ID/ID-334-W.pdf.

[39] David J. Schingoethe, Dairy Science Department, South Dakota State University, *Can We Feed More Distillers Grains?*, Tri-State Dairy Nutrition Conference, April 25-26, 2006. http://www.poetenergy.com/files/division_files/Tri-State%20DNC%20Schingoethe%20DDGS%2006%20rev%20Posted%207-28-06.pdf.

[40] Daniel D. Loy, Professor of Animal Science, Iowa State University Extension, Iowa State University, Daryl Strohbehn, Professor of Animal Science, Iowa State University Extension, and Wendy Miller, Communications Specialist, Iowa Beef Center, "Distillers Grains for Beef Cows" *in Ethanol Coproducts for Cattle,* Iowa State University, Iowa Beef Center (IBC-26), September 2005. http://www.extension.iastate.edu/Publications/IBC26.pdf.

[41] Daniel D. Loy, Professor of Animal Science, Iowa State University and Wendy Miller, Communications Specialist, Iowa Beef Center, "The Processes and Products" in *Ethanol Coproducts for Cattle* (IBC-18), February 2002.

Table 2.	Distilled Dried Grains Solubles	Distillers Dried Grains	Cond. Distillers Solubles	Wet Distillers Grains
Dry Matter	90	90	30	30 - 50
Protein	27.8 - 30.4	30	24 - 28.5	30 - 32
Fat	8.9 - 10.7	8.4	9 - 14.5	8.5 - 12.5
Fiber	6.9 - 10.1	14.4	4	--
ADF	18 - 21	18	2 - 7	14 - 22
NDF	44 - 46	44	10 - 23	30 - 50
TDN	85 - 90	77	75 - 120	70 - 110
NEm	0.99	0.89	1.05 - 1.15	0.9 - 1.1
NEg	0.68	0.67	0.85 - 0.93	0.7 - 0.8
Ca	0.17 - 0.26	0.11	0.03 - 0.17	0.02 - 0.03
P	0.78 - 0.83	0.41	1.3 - 1.45	0.5 - 0.8
K	0.49 - 1.08	0.18	1.75 - 2.25	0.5 - 1
Mg	0.2 - 0.33	0.08	0.65 - 0.9	0.2 - 0.3
Na	0.3 - 0.63	1	0.3 - 20	0.1 - 0.2
S	0.37 - 0.44	0.48	0.37 - 0.95	0.5 - 0.7
Fe	258 - 358	222	227 - 600	90 - 180
Cu	10 - 64	49	17 - 83	6 - 7
Zn	67 - 89	--	103	40 - 60
Mn	28 - 27.6	--	34	8 - 16

1. **Distillers Solubles.** Thin stillage, the liquid portion of the distillers fermentation coproduct, may be processed as condensed distillers solubles (CDS) or dried as distillers dried solubles. Distillers solubles are higher in fat and lower in fiber than wet distillers grains, and therefore appear to have a higher energy value.[42] Typically distillers solubles are processed as condensed distillers solubles (CDS), and blended with a form of distillers grains. Indeed, it is tacitly assumed that distillers grains contain solubles even when they are not specifically identified.[43]

2. **Wet Versus Dry Forms**. Wet distillers grains with solubles (WDGS) contain the highest energy value, equal to at least 125 percent of corn when used as a beef finishing diet.[44] Compare this to wet corn gluten feed which may have up to 100 to 110 percent of the energy value of corn, depending on the steep level in gluten feed.[45] Research indicates that wet distillers grains without solubles has an energy value similar to corn.[46] According to available data, distillers dried grain may have the same energy value to corn.

3. **Variation.** The composition of distillers grains are not standardized and producers may receive feed which has a degree of variation in its elements, including in protein content. For example DDGS are typically advertised having a conservative estimate of protein (e.g., 25 percent) which ensures that feed meets label specifications, although the protein content may be 5-10 percent units higher than the guaranteed minimum specification stated on the label.[47] Variation in fiber and energy content have similar variations which may impact diet quality.[48] An

[42] Loy and Miller, "Wet Distillers Feeds for Feedlot Cattle Long Term Storage of Wet Distillers Grains and CDS", supra.
[43] Schingoethe, *Can We Feed More Distillers Grains?*, supra.
[44] Loy and Miller, "Wet Distillers Feeds for Feedlot Cattle Long Term Storage of Wet Distillers Grains and CDS", supra.
[45] G. E. Erickson,T. J. Klopfenstein, D. C. Adams, R. J. Rasby, Department of Animal Science University of Nebraska-Lincoln, "General Overview of Feeding Corn Milling Coproducts to Beef Cattle" in *Corn Processing Coproducts Manual, A Review of Current Research on Distillers Grain and Corn Gluten, supra at 11.* Nebraska Corn Board and the University of Nebraska-Lincoln Institute of Agriculture and Natural Resources Agricultural Research Division Cooperative Extension Division. http://www.nebraskacorn.org/publications/coproducts_processing.pdf.
[46] Loy and Miller, "Wet Distillers Feeds for Feedlot Cattle Long Term Storage of Wet Distillers Grains and CDS", supra.
[47] Rausch and Belyea, *Coproducts from Bioprocessing of Corn,* supra at p.13.
[48] Id.

important issue affecting variation in dried forms of distillers grains is damage occurring during drying which may affect the nutrient content and digestibility of the feed.[49] Excessively "toasted" distillers dried grains may result in heat-damaged protein that is indigestible by dairy cattle. Variations may be due to drying times, temperatures, and drying equipment may contribute to differences in the nutritional quality among operations and between batches from the same operation.[50]

4. Separate Nutritional Needs for Beef and Dairy Production. For cattle, the amount of distillers grains used to replace a diet of corn varies depending upon whether the operation is devoted to dairy or beef production. For example beef cattle are typically fed rations that contain a higher percentage of oil (taking energy value from fat) in order to achieve higher rates of gain. For dairy cattle, a lower percentage of oil is preferred to avoid decreasing feed intake and consequently lower milk production.[51] Studies indicate that milk production and the composition of milk is not adversely affected by incorporating 20 percent distillers grains into the diet of lactating cows, assuming recommended ration formulations are followed.[52] For cattle operations maintained for beef production distilled grain may be fed at low levels as supplemental protein as the primary source of energy, replacing corn. Cattle have been fed distilled grains up to 40 percent with some accompanying reduction in marbling (i.e., the number and size of fat cells), but without affecting meat tenderness, juiciness, and flavor, or the net value of carcasses.[53] The limit for feeding distillers grains to beef cattle is approximately 50 percent when calculated on a dry matter basis, assuming no changes in milling technology that reduce oil or sulfur content[54] which could theoretically extend the level to 70 percent in a limit-fed, high concentrate ration.[55] An unfavorable ratio of calcium to phosphorous may occur at high levels which may be overcome by increasing calcium supplements.[56] NOTE: Iowa State University has produced a series of spreadsheet programs entitled Beef Ration and Nutrition Decisions Software (BRANDS) to assist producers in balancing rations for beef cattle.[57]

5. Sulfur. Sulfur is an intrinsic element in corn and is produced during the fermentation process.[58] However, sulfuric acid is also added during both the wet milling and dry grinding milling process, although the two different types of plants utilize sulfuric acid differently. During the wet milling process, products may be steeped in sulfuric acid, while during the dry grinding process, sulfuric acid is added in part to maintain pH at a level which is conducive to yeast cells.[59] The amount of sulfur content has been an issue for both types of milling operations, and may be the primary factor which restricts the amount of distillers grains that may be fed to cattle.[60] At

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[49] Lardy, *Feeding Coproducts of the Ethanol Industry to Beef Cattle,* supra.
[50] Donkin, Johnson, and Schutz, *Value of Distillers' Grains for Lactating Dairy Cows,* supra.
[51] Hardy, Holz-Clause, Shepherd, and Hurburgh, *Sourcing Corn for Ethanol: Impacts of Local Processing,* supra at 9.
[52] David J. Schingoethe, Dairy Science Department, South Dakota State University, *Can We Feed More Distillers Grains?,* supra.
[53] Daniel D. Loy, Professor of Animal Science, Iowa State University, "Do Distillers Grains Affect Beef Quality," in *Ethanol Feeds Feeding Distillers Grains to Beef Cattle,* p.1. December 2006. http://www.iowabeefcenter.org/content/Distillers_Newsletter_December_06.pdf.
[54] Daniel D. Loy, Professor of Animal Science, Iowa State University, "How Much Distillers' Grains Can I Feed" in *Ethanol Feeds Feeding Distillers Grains to Beef Cattle,* p. 1. February 2007. http://www.iowabeefcenter.org/content/Distillers_Newsletter_February_2007.pdf.
[55] Daniel D. Loy, Professor of Animal Science, Iowa State University Extension, Iowa State University and Daryl Strohbehn, Professor of Animal Science, Iowa State University Extension, *Iowa Beef Center, Ethanol Coproducts FAQ (Frequently Asked Questions).* http://www.iowabeefcenter.org/content/ethanolcoproductsfaq.htm.
[56] Loy and Strohbehn, *Iowa Beef Center, Ethanol Coproducts FAQ (Frequently Asked Questions)* supra.
[57] See Iowa Beef Center http://www.iowabeefcenter.org/content/brandsmain.htm.
[58] Tracy A. Snider, PAS, *Distillers Grains and Sulfur White Paper,* National Corn Growers Association, April 30, 2004. http://www.ddgs.umn.edu/articles-proc-storage-quality/2004-Snider-%20DG%20and%20sulfur--.pdf.
[59] Snider, PAS, *Distillers Grains and Sulfur White Paper,* supra.
[60] Daniel D. Loy, Professor of Animal Science, Iowa State University, "How Much Distillers' Grains Can I Feed", supra at p. 1.

excessive rates, sulfur intake may impair the performance of livestock because it reduces an animal's ability to absorb other minerals. Using recommendations by the National Research Council, Iowa State University estimates that based solely on sulfur content, the maximum level of distillers grains that could be fed to cattle on a dry matter basis would range from 30 percent using high sulfur levels to 70 percent using low sulfur levels.[61] Knowing the sulfur content of a particular lot of feed would assist livestock producers in adjusting their feed rations or management practice to avoid the effect of sulfur toxicity. Presumably, this is the rationale for the adoption of a rule by the South Dakota Department of Agriculture requiring that corn gluten feed distillers products and corn gluten feed (as defined in the Official Publication of the Association of American Feed Control Officials) must state the maximum sulfur in the product in terms of percentage.[62] The rule reads as follows:

> **12:53:01:18. Maximum sulfur percentage required on label of distillers products and corn gluten feed.** The label of distillers products and corn gluten feed, as defined in the Official Publication of the Association of American Feed Control Officials, Incorporated, 2003 Edition, pages 244-245 and 263, must state the maximum sulfur in the product. The sulfur guarantee must be stated in terms of percentage.[63]

6. Environmental Impacts. Distillers grains with or without solubles and in either a wet or dried form contain concentrated minerals, including variable levels of phosphorus and nitrogen. The concentration of phosphorus and nitrogen are primarily issues involving nutrient management rather than animal health or performance (and especially affecting livestock operations with limited available land for manure application). Increasing the proportion of the diet that contains distillers grains increases the amount of manure phosphorus excreted. For example, a 40 percent DDGS diet increases manure phosphorus by a comparable amount, and results in more acres needed to apply manure phosphorus on corn cropland. Compare this to the same use of DDGS which results in greater nitrogen excretion levels, but which does not require more acres for manure application on corn cropland (i.e., resulting in a nitrogen deficit after application). Presumably, if milling operations could produce forms of distilled grains which reduced phosphorus levels distilled, coproducts could be marketed to a broader range of species including swine.[64]

MANURE ACREAGE REQUIREMENT BASED ON PHOSPHORUS AND NITROGEN USE[65]

	Percent of DDGS in the diet (dry matter basis)			
	0	15	25	40
Corn acres need for phosphorus use (60 lb/acre P_2O_5)	769	923	1,077	1,308
Corn acres need for nitrogen use (180 lb/acre N)	333	333	400	494
Nitrogen deficit (lb/acre)	102	115	113	112

[61] Id.
[62] Snider, PAS, Distillers Grains and Sulfur White Paper, supra.
[63] Id.
[64] Hardy, Holz-Clause, Shepherd, and Hurburgh, Sourcing Corn for Ethanol: Impacts of Local Processing A Project of the Iowa Grain Quality Initiative, supra at p. 9.
[65] Wendy Powers, Associate Professor of Animal Science, Iowa State University Extension; Dan Loy, Professor of Animal Science, Iowa State University Extension; Allen Trenkle, Professor of Animal Science, Iowa State University Extension; and Rachel E. Martin, Communications Specialist, Iowa Beef Center, Iowa State University, *Use of Distillers Grains in Feedlot Diets Impact on Phosphorus Excretion* (IBC-29), p. 2. July 2006. http://www.extension.iastate.edu/Publications/IBC29.pdf.

V. CONCLUSION

Ethanol production from milling operations, and particularly grinding milling operations, are rapidly expanding in Iowa, demanding an increasing quantity of feedstock, which currently is corn. Distilled coproducts, and especially dry distillers grains with solubles (DDGS) derived from dry grind milling operations promise to provide an important feed source for beef and dairy cattle, regardless of whether the coproduct is in a wet, modified, or dry form. However, the utility of distilled coproducts depends upon a number of factors including how they are processed, handled, transported, and stored. Therefore, it is important that producers have adequate information to formulate rations to ensure optimal nutritional value and provide for sound management practices. This memorandum takes no position about how that information should be best obtained.

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