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Market Issues and Prospects for U.S. Distillers' Grains
Supply, Use, and Price Relationships

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Abstract

Growth in corn dry-mill ethanol production has surged in the past several years, simultaneously creating a coproduct—distillers' grains (DDGS). Many in the U.S. feed industry were concerned about the size of this new feed source and whether it could be used entirely by the feed industry, but they also worried about the price discovery process for the product. The authors of this report provide a transparent methodology to estimate U.S. supply and consumption of DDGS. Potential domestic and export use of U.S. DDGS exceeds current production and is likely to exceed future production as ethanol production continues to grow. The authors identify the DDGS price discovery process along with the price relationships of distillers' grains, corn, and soybean meal.

Keywords

Distillers' dried grains with solubles (DDGS), dry-mill ethanol production, wet-mill ethanol production, feed use, exports, potential DDGS feed consumption, distillers' grain price discovery, and distillers' grain price relationships.

Acknowledgments

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Introduction

Growth in U.S. ethanol production seems certain for the near- to mid-term, stimulated, in part, by longer run energy prices and the 2005 and 2007 Energy Acts.[1] In 2005/06, 4.5 billion gallons of ethanol were produced. By 2008/09, production more than doubled to 10.2 billion gallons, with a corresponding increase in distillers' grains (DDGS),[2] a coproduct of ethanol production that can be used as a livestock feed.[3] Prices for corn, a feedstock for both ethanol and livestock feed, and other feed-related products have risen, causing concern for the financial viability of livestock and poultry producers. The use of distillers' grains continues to expand and partially replace corn and soybean meal in the U.S. feed market. DDGS can supply both energy and protein in livestock and poultry rations, but use may be limited due to nutritional or price considerations. Prices of DDGS relative to alternative feed ingredients would need to adjust to reflect its nutrient content. As the industry expands, producers may wonder about the price relationships between DDGS, corn, and soybean meal.

Distillers' grains have long been substituted for corn and soybean meal, but as the market expands, questions remain over the substitution rate of DDGS for energy (corn) and protein (soybean meal) in livestock and poultry rations. As the market expands, industry analysts may be concerned about:

- The relative balance between supply and disappearance, regardless of increased DDGS feeding familiarity by feeders and the improvement of DDGS product quality (Cooper, 2006);

- The supply of U.S. DDGS exceeding feed-use potential;

- The potential use of DDGS for domestic or export purposes; and

- Current or future U.S. production of DDGS exceeding potential uses.

The growth in this new feed market reinforces the need for a transparent methodology to estimate supply and consumption for the U.S. distillers' grain market. Currently, production estimates are made by the U.S. Census Bureau (U.S. Department of Commerce (a)), the Renewable Fuels Association (*Ethanol Industry Outlook* for 2008, 2009, and 2010), and other research organizations. The U.S. Census Bureau began providing estimates of distillers' grain production in early 2007. These production estimates were considered incomplete by many Government and industry analysts. Other production estimates lack transparency and comparability. So, until the U.S. Census Bureau estimates are more complete and reflect ethanol production data, a transparent estimation method would serve both the Government and the industry, offering estimates for the production and consumption of distillers' grains. Data on ethanol coproduct feed use (distillers' grains, corn gluten feed, and corn gluten meal) will be valuable for those conducting analytical analyses of the U.S. feed sector (e.g., Ferris, 2006).

[1] In addition to Government policies and longer run energy prices, the growth rate of the ethanol market depends, in part, on feedstock costs, changes in technology, and changes in Government incentives.

[2] The term "distillers' grains" refers to coproducts generated by dry-mill ethanol plants, including distillers' wet grains (DWG), distillers' dried grains (DDG), distillers' wet grains with solubles (DWGS), distillers' dried grains with solubles (DDGS), and condensed distillers' solubles (CDS). Unless otherwise specified for the remainder of this report, the term distillers' grains will mean distillers' dried grains with solubles (DDGS).

[3] Ethanol production numbers are expressed in terms of corn's September-August marketing year (U.S. Energy Information Administration, 2010).

This report details the development of the U.S. distillers' grains market and provides a transparent methodology (see "Appendix: Estimation of U.S. Distillers' Grains Supply and Use") to estimate supply and use of distillers' grains. The authors of this study examined price discovery and risk management of distillers' grains along with the price relationships of DDGS, corn, and soybean meal.

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Estimating U.S. Distillers' Grain Supply and Use

The surge in ethanol production over the last several years has been paralleled by a surge in the production of distillers' grains. Currently, consistent data do not exist to measure this rapidly growing segment of the feed industry. We offer a methodology that produces a transparent source of information to gauge the supply and use of distillers' grains (table 1). For production, we estimated the amount of corn used by beverage distilleries and the resulting amount of distillers' grains produced from this process. We also estimated the amount of corn used by dry-mill ethanol plants and the resulting distillers' grains. We then added imports of distillers' grains based on trade data from the U.S. Department of Commerce (b) and from the Economic Research Service's Feed Grains Database (2010). By combining these components, we estimated the total supply of distillers' grains. From this supply, we subtracted exports based on trade data from the same two sources to arrive at feed and residual use. Details of this estimation procedure can be found in the appendix.

Table 1

Supply and disappearance of corn-based distillers' grains (DDGS)

Marketing year	Column 1 Distillers' spent grains from beverage distilleries		Column 2 Production Distillers' spent grains from dry mill plants producing ethanol[1]		Supply Total		Column 3 Imports Brewers' and distillers' dregs and wastes[2,3]		Supply Total	Column 4 Feed and residual		Column 5 Disappearance Exports Brewers' and distillers' dregs and wastes[2,3]		Disappearance Total
	Million metric tons	Percent of total production	Million metric tons	Percent of total production	Million metric tons	Percent of total supply	Million metric tons	Percent of total supply	Million metric tons	Million metric tons	Percent of total disappearance	Million metric tons	Percent of total disappearance	Million metric tons
1992/93	0.8	40	1.2	60	2.0	97	0.1	3	2.1	2.1	100	0.0	0	2.1
1993/94	0.6	27	1.6	73	2.2	96	0.1	4	2.3	2.1	92	0.2	8	2.3
1994/95	0.5	35	1.0	65	1.5	94	0.1	6	1.6	0.9	55	0.7	45	1.6
1995/96	0.8	77	0.2	23	1.0	93	0.1	7	1.1	0.5	41	0.6	59	1.1
1996/97	0.8	64	0.5	36	1.3	91	0.1	9	1.4	0.8	53	0.7	47	1.4
1997/98	0.9	52	0.8	48	1.6	94	0.1	6	1.7	1.1	65	0.6	35	1.7
1998/99	0.8	47	1.0	53	1.8	93	0.1	7	1.9	1.2	62	0.7	38	1.9
1999/00	0.9	51	0.9	49	1.7	92	0.1	8	1.9	1.1	59	0.8	41	1.9
2000/01	0.9	36	1.6	64	2.5	95	0.1	5	2.6	1.8	70	0.8	30	2.6
2001/02	0.9	31	2.0	69	2.9	96	0.1	4	3.0	2.1	72	0.9	28	3.0
2002/03	0.9	17	4.3	83	5.2	98	0.1	2	5.3	4.6	86	0.8	14	5.3
2003/04	0.9	13	6.1	87	7.0	99	0.1	1	7.1	6.4	90	0.7	10	7.1
2004/05	0.9	11	7.3	89	8.2	99	0.1	1	8.3	7.4	88	1.0	12	8.3
2005/06	0.9	9	9.5	91	10.4	99	0.1	1	10.5	9.3	88	1.2	12	10.5
2006/07	0.9	7	13.2	93	14.1	99	0.2	1	14.3	12.5	88	1.8	12	14.3
2007/08	0.9	4	20.5	96	21.4	100	0.1	0	21.5	17.6	82	3.9	18	21.5
2008/09	0.9	3	25.6	97	26.5	99	0.3	1	26.8	21.8	81	5.0	19	26.8
2009/10[4]	0.9	3	32.0	97	32.9	99	0.4	1	33.3	25.0	75	8.3	25	33.3
2010/11[4]	0.9	3	33.2	97	34.1	99	0.5	1	34.6	25.9	75	8.7	25	34.6

[1]Does not account for noncorn spent grains.

[2]Assumes brewers' spent grains are minor.

[3]May contain noncorn brewers' and distillers' dregs and wastes.

[4]Estimates are from the September 10, 2010 *World Agricultural Supply and Demand Estimates* and Feed Grains Database.

Source: Distillers' spent grains from beverage distilleries are from U.S. Department of the Treasury, Alcohol and Tobacco Tax and Trade Bureau; monthly statistical reports, 1992-2010, http://www.ttb.gov/statistics/alcohol_stats.shtml#alcoholfuel; distillers' spent grains from dry-mill ethanol plants are from table 3 of this report (corn used for dry-mill ethanol plants multiplied times 17.5 pounds of distillers' grains per bushel of corn processed for 1992/93 through 2006/07 and 17.4 pounds of distillers' grains per bushel of corn processed for 2007/08 through 2010/11); imports and exports are taken from USDA, Economic Research Service, Feed Grains Database or U.S. Department of Commerce (b).

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Total Supply of U.S. Distillers' Grains Accelerates Over the Past 4 Years

The estimated supply of U.S. distillers' grains is expected to total 33.3 million metric tons for 2009/10, more than four times that in 2003/04 (see table 1) (see also, "Appendix: Estimation of U.S. Distillers' Grains Supply and Use" for an explanation of the methodology that provided these estimates.) Most distillers' grains come from dry-mill fuel ethanol production and a lesser amount comes from dry-mill beverage distilleries. Imports are a minor segment of the market.[4] Most distillers' grains are derived from corn with smaller amounts coming from sorghum and wheat. Changes in dry-mill ethanol technology may further alter the composition of distillers' grains. Growth in distillers' grain production will continue to follow corn use for ethanol production, but both are expected to slow compared with the rapid expansion over the past several years (USDA, February 2010).

[4] Most of these imports originated in Canada and their feedstock is unknown, perhaps consisting of wheat, barley, or corn. Since the quantity is small, the concern over the feedstock is less important.

Long History of Using DDGS as a Livestock Feed

Distillers' grains, a byproduct of dry-mill beverage and ethanol fuel production, have long been fed to livestock. In the late 19th century, the alcoholic beverage distilling industry pioneered the act of recovering nutrients from grains that had undergone fermentation (Schingoethe, 2004). Distillers' grains are the spent coproducts of the fermentation and distillation process. These distillers' grains were recognized as an excellent feed for dairy cattle.[5]

Ethyl alcohol was critical for the manufacture of munitions during World War II, and the beverage industry (dry-mills) met most of this demand (Weiss et al., 2007). Since then, several factors have contributed to the expansion of U.S. ethanol fuel production from both wet- and dry-mill processing plants:

[5] Brewers' grains, a byproduct of beer manufacturing, also has a long history of use in the livestock feed market. Currently, the quantities of these beer-manufacturing byproducts are dwarfed in comparison with the quantity of distillers' spent grains being produced. Most of the brewers' grains are reportedly fed in the wet form to nearby livestock feeders (Ash, p. 91).

- The world oil crisis in the 1970s;
- State and Federal subsidies for ethanol production;
- Clean air legislation in the early 1990s;
- Ethanol's use as an octane enhancer;
- The replacement of methyl tertiary butyl ether (MTBE); and
- Rising energy costs and mandates for biofuel use in the Energy Acts of 2005 and 2007.

Corn Is Main Feedstock for Ethanol Production

Corn is the primary grain used in wet- and dry-mill ethanol plants (accounting for about 98 percent of all ethanol feedstocks) because its starch content is highly fermentable. Some ethanol plants use sorghum or a blend of corn with barley, wheat, or sorghum. Other plants may use excess whey, beverage, or sugar wastes as a feedstock. The decision to use a particular feedstock depends upon the geographical location, costs, and availability of other feedstocks relative to corn. In the future, biomass from other sources (e.g., grasses, wood pulp, or crop residue) may contribute more feedstock for ethanol production (Coyle, 2010).

Different Feed Coproducts from Wet Versus Dry Processes

Grain-based fuel ethanol production results from two main processes—wet and dry corn milling. Although ethanol production changes corn's feed value by removing most of the starch content, the remaining ethanol coproduct retains the following nutrients: protein, minerals, fat, fiber, and vitamins. Because ethanol production processes differ, the coproducts also differ. For example, wet corn mills produce corn gluten feed and corn gluten meal. Dry corn mills produce distillers' spent grains. More recently, fractionation technologies used by some plants has begun to change the composition of distillers' spent grains from the dry-mill process.[6]

Wet milling—The wet-milling process removes the maximum amount of starch from the kernel by first adding water to the grain and allowing it to steep so the starch can be removed, along with the corn bran, corn gluten meal (protein), germ, and soluble components. Since this process separates the germ (from which corn oil is extracted), corn oil is one coproduct produced from the wet-milling process regardless of other products produced, including starch, high fructose corn syrup (HFCS), glucose/dextrose, and/or ethanol. Feed byproducts from the wet process include corn gluten feed, corn gluten meal, and corn germ meal.[7, 8] These coproducts can be fed to livestock in either wet or dry form. Corn gluten feed usually consists of corn bran, steeping liquid, and germ meal. One bushel of corn processed by a wet mill yields about 12.9 pounds of corn gluten feed and 3.1 pounds of corn gluten meal (Watson, 1977), plus carbon dioxide, and about 2.7 gallons of ethanol (Rendleman and Shapouri, 2007). The protein content of corn gluten feed is usually about 21 percent (as fed), while corn gluten meal's protein content is around 60 percent (as fed).[9] We estimate that 475.1 million bushels of corn were used by corn wet mills to produce fuel ethanol during 2009/10 (table 2) (see also, "Appendix: Estimation of U.S. Distillers' Grains Supply and Use" for an explanation of the methodology that provided these estimates).

Dry milling—The dry milling process (mash distillation) cleans and grinds the grain to reduce the particle size; usually the entire corn kernel is used in fermentation. Corn is about two-thirds starch, which is converted into ethanol and carbon dioxide during the distillation and fermentation process. The remaining third consists of distillers' grains. A bushel of corn processed into ethanol by dry mills produces approximately 17.5 pounds of distillers' spent grains, carbon dioxide, and 2.7 gallons of ethanol. The nutrient content (protein, fat, minerals, and vitamins) of the spent grains increases by three times because prior to fermentation these nutrients represented only about a third of corn's dry matter.[10]

While there are several different forms of distillers' coproducts from dry-mill ethanol plants, most of the distillers' spent grains are dried and sold as distillers' dried grains with solubles (DDGS). The liquid removed from the mash is called thin stillage. Some of the thin stillage can be directed back to the cooking and distillation process to reduce the amount of fresh water required by the cooking and distillation process, and the remainder can be sold directly as high-moisture cattle feed or dehydrated to produce condensed distiller's solubles (CDS). The residual solids (coarse grains fraction) are

[6] These fractionation technologies will be explained later in this report. See p.12, "Composition of Distillers' Grains is Beginning to Change."

[7] Currently, USDA reports (Feed Grains Database, yearbook table 29) quantities of corn gluten feed and corn gluten meal that are produced when making starch, high fructose corn syrup, and dextrose. Estimates of corn gluten feed and corn gluten meal that are produced from wet-mill ethanol production were unavailable and thus not included in the quantities reported in table 29. Consequently, the quantity of wet-mill feed coproducts is under-reported. New estimates of corn gluten feed and corn gluten meal produced from corn wet mills are made to account for this under-reporting and provided later in this report.

[8] For more information on the wet corn milling process and the feed coproducts produced, see *Corn Wet Milled Feed Products*, pp. 6-11, http://www.corn.org/wp-content/uploads/2009/12/Feed2006.pdf, (Corn Refiners Association, 2006); *How Ethanol Is Made* at http://www.ethanolrfa.org/resource/made/ (Renewable Fuels Association, 2010); or *Feed Co-Products of the Corn Wet Milling Process* at http://www.extension.iastate.edu/Bioeconomy/Livestock/ (Weigle et al., 2004).

[9] "As fed" or "as is basis" means that there is no adjustment for moisture content in comparison with dry matter basis where adjustments are made for moisture content.

[10] For more information on the dry mill process and the feed coproducts produced, see *How Ethanol Is Made* at http://www.ethanolrfa.org/resource/made/ (Renewable Fuels Association, 2010) or *Feed Co-Products of the Dry Corn Milling Process* at http://www.extension.iastate.edu/Bioeconomy/Livestock/ (Weigel et al., 2004).

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Table 2
Estimation of U.S. corn use for wet-mill ethanol production

Crop year	Column 1 Total[1] (Corn oil production)	Column 2 Adjusted for dry mill products[2]	Column 3 for wet-mill corn oil production[3] (Corn use)	Column 4 High fructose corn syrup	Column 5 Glucose/ dextrose	Column 6 Starch	Column 7 Sum of three products	Column 8 Ethanol
	----Thousand pounds----		----Million bushels----				(Corn used to produce various wet-mill products)	
1992/93	1,866,203	1,834,478	1,118.6	414.8	214.3	217.6	846.7	271.9
1993/94	1,906,233	1,873,827	1,142.6	441.0	219.2	224.9	885.1	257.5
1994/95	2,201,751	2,164,321	1,319.7	458.6	224.5	230.4	913.6	406.1
1995/96	2,155,459	2,118,816	1,292.0	472.9	227.3	226.1	926.3	365.7
1996/97	2,223,434	2,185,636	1,332.7	492.3	232.9	238.3	963.4	369.3
1997/98	2,328,157	2,288,578	1,395.5	528.0	236.5	248.1	1,012.6	382.9
1998/99	2,366,952	2,326,714	1,418.7	544.0	226.3	242.5	1,012.8	405.9
1999/00	2,491,224	2,448,873	1,493.2	551.9	229.3	253.4	1,034.6	458.6
2000/01	2,406,507	2,365,596	1,442.4	536.2	226.7	250.0	1,012.9	429.5
2001/02	2,453,609	2,411,898	1,470.7	542.2	226.5	248.8	1,017.5	453.1
2002/03	2,460,883	2,419,048	1,475.0	532.2	231.0	258.2	1,021.4	453.6
2003/04	2,399,561	2,358,768	1,438.3	529.8	238.3	273.3	1,041.4	396.9
2004/05	2,407,167	2,366,245	1,442.8	525.1	234.5	282.0	1,041.6	401.2
2005/06	2,462,773	2,420,906	1,476.2	545.0	245.1	280.4	1,070.5	405.7
2006/07	2,559,870	2,511,232	1,531.2	535.3	259.4	276.9	1,071.6	459.6
2007/08	2,508,917	2,458,739	1,499.2	522.8	256.0	264.7	1,043.5	455.7
2008/09	2,409,981	2,355,756	1,436.4	489.1	245.0	234.1	968.2	468.2
2009/10[4]	2,500,000	2,443,750	1,490.1	515.0	255.0	245.0	1,015.0	475.1
2010/11[4]	2,575,000	2,517,063	1,534.8	525.0	260.0	250.0	1,035.0	499.8

[1]Historical corn oil production data from the U.S. Department of Commerce (a), Census Bureau, *Fats and Oils: Oilseed Crushings Circular*, M311J, table 2, and from *Corn Oil*, http://www.census.gov/manufacturing/cir/historical_data/historical_data/m311j/index.html Adjusted to corn crop year, September-August.

[2]Corn oil projections for 1992/93-2005/06 are reduced by 1.7 percent to account for dry-mill corn oil production. Reductions for 06/07 = 1.9 percent; 07/08 = 2.0 percent; 08/09 = 2.25 percent; 09/10 = 2.25 percent; and 10/11 = 2.25 percent to account for fractionation oil removal.

[3]Assumes corn oil yield of 1.64 pounds/bushel.

[4]Corn oil projections from the September 13, 2010, *Oil Crops Outlook*; wet-mill products, excluding ethanol, from the September 14, 2010, *Feed Grains Outlook*, p. 15.

Source: USDA, Economic Research Service calculations based on data from U.S. Department of Commerce (a), Census Bureau, *Fats and Oils: Oilseed Crushings Circular*; Economic Research Service *Oil Crops Outlook*.

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referred to as wet distillers' grains and can be used as cattle feed or dried to produce dried distillers' grains (DDG). CDS can be used as cattle feed or blended with distillers' grains to produce DDGS. Distillers' grains with solubles are sold wet (WDGS; 30 to 35 percent dry matter), modified (MDGS; 45 to 50 percent dry matter), or dried (DDGS; 88 to 90 percent dry matter). Distillers' grains can be fed either wet or dry. Approximately 36 percent of the distillers' grains with solubles fed in the United States are wet and 64 percent are dry (Renewable Fuels Association, *Ethanol Industry Outlook*, 2009). The authors of this report will focus specifically on DDGS and convert all distillers' grains into an equivalent DDGS weight.

Supplies of Ethanol Coproducts Rapidly Expanding

Most of the expansion in ethanol fuel production has come from dry-mill plants with little additional capacity expansion from wet mills. Wet mills are more expensive to build, more versatile in the products they can produce, yield slightly less ethanol per bushel, and offer more valuable coproducts. Wet mills used to account for most of the U.S. ethanol production, but new construction has shifted to dry mills, partly because dry mills are less costly to build. For 2009/10, we estimate that 11 percent of U.S. fuel ethanol was produced in wet mills with the remaining 89 percent produced in dry mills, compared with 2001/02 when wet mills produced 64 percent and dry mills 36 percent of total ethanol production (table 3).

Table 3
Estimation of corn use for dry-mill ethanol production

Crop year	Column 1 Total corn use for fuel ethanol production[1]	Column 2 Corn use for wet-mill ethanol production[2]	Column 3 Corn use for dry-mill ethanol production[2]	Percent used by mill type		
				Wet mills	Dry mills	Total
	---------------------Million bushels--------------------			------------------- Percent -----------------		
1992/93	425.5	271.9	153.6	63.9	36.1	100
1993/94	458.3	257.5	200.7	56.2	43.8	100
1994/95	532.8	406.1	126.6	76.2	23.8	100
1995/96	395.7	365.7	30.0	92.4	7.6	100
1996/97	428.7	369.3	59.4	86.1	13.9	100
1997/98	481.1	382.9	98.2	79.6	20.4	100
1998/99	525.8	405.9	119.9	77.2	22.8	100
1999/00	565.8	458.6	107.1	81.1	18.9	100
2000/01	627.6	429.5	198.1	68.4	31.6	100
2001/02	705.9	453.1	252.8	64.2	35.8	100
2002/03	995.5	453.6	541.9	45.6	54.4	100
2003/04	1,167.5	396.9	770.7	34.0	66.0	100
2004/05	1,323.1	401.2	921.8	30.3	69.7	100
2005/06	1,602.8	405.7	1,197.1	25.3	74.7	100
2006/07	2,119.0	459.6	1,659.4	21.7	78.3	100
2007/08	3,049.0	455.7	2,593.3	14.9	85.1	100
2008/09	3,709.0	468.2	3,240.8	12.6	87.4	100
2009/10[3]	4,535.0	475.1	4,059.9	10.5	89.5	100
2010/11[3]	4,700.0	499.8	4,200.2	10.6	89.4	100

[1]Based on USDA, Economic Research Service, Feed Grains Database. [2]Based on table 2 of this report. [3]Corn use for ethanol production from September 10, 2010, *World Agricultural Supply and Demand Estimates*.
Source: USDA, Economic Research Service, Feed Grains Database; table 2 of this report.

Production of distillers' grains, a feed coproduct from corn dry-mill ethanol production, surpassed feed coproducts from the wet-milling process (namely corn gluten feed and corn gluten meal) in marketing year 2006/07 (table 4).[11] Between 1992/93 and 2001/02, exports accounted for most of corn gluten feed's disappearance, but export's recent share of corn gluten feed has declined. This decline in corn gluten feed was due to the European Union's Common Agricultural Policy (CAP) reform and from the adoption of genetically modified corn in the United States. For example, cereal prices declined when CAP reform stimulated consumption of domestic feed. EU reforms also reduced the EU cow herd, which reduced the need for feed. Furthermore, U.S. corn gluten feed and its derivation from genetically modified corn may have precluded its use in EU feed rations.[12] This biotechnology concern may be present regardless of whether U.S. corn wet mills used only EU-approved corn varieties, due to fear of contamination of unapproved varieties. Tables 5 and 6 provide estimates of U.S. corn gluten feed and meal supply and disappearance.

As the production of corn-based ethanol increases, DDGS output increases because of the fixed proportions of ethanol and coproduct yield from corn bushels processed. For example, when dry-mill fuel ethanol production began to accelerate between 2002/03 and 2009/10 and dry-mill corn use rose from an estimated 0.5 to 4.1 billion bushels (see table 3), production of DDGS rose from an estimated 4.3 to 32.0 mmt (million metric tons) (see table 1).

[11] The production estimates for corn gluten feed and corn gluten meal reflected in table 4 compute the total produced from making HFCS, glucose/dextrose, starch, and ethanol. Existing ERS estimates from table 29 compute corn gluten feed and corn gluten meal from only the production of HFCS, glucose/dextrose, and starch (USDA, ERS, Feed Grains Database, yearbook table 29, 2010).

[12] Similar concerns can be expressed about the U.S. DDGS market and may account for much of the decline in U.S. sales of DDGS to Europe, a topic addressed later in this report.

Table 4
Estimates of feed coproducts from corn wet- and dry-mill related production processes

	Corn wet-mill production							Corn dry-mill production		
	HFCS, Glucose/dextrose, and starch		Ethanol		Total			Beverage ethanol	Fuel ethanol	Total
	Corn gluten:		Corn gluten:		Corn gluten:		Grand total	Distillers' grains produced from beverage and fuel production		
Crop year	Feed	Meal	Feed	Meal	Feed	Meal				
	--- Million metric tons ---									
1992/93	5.0	1.2	1.6	0.4	6.5	1.6	8.1	0.8	1.2	2.0
1993/94	5.2	1.2	1.5	0.4	6.7	1.6	8.3	0.6	1.6	2.2
1994/95	5.3	1.3	2.4	0.6	7.7	1.9	9.6	0.5	1.0	1.5
1995/96	5.4	1.3	2.1	0.5	7.6	1.8	9.4	0.8	0.2	1.0
1996/97	5.6	1.4	2.2	0.5	7.8	1.9	9.7	0.8	0.5	1.3
1997/98	5.9	1.4	2.2	0.5	8.2	2.0	10.1	0.9	0.8	1.6
1998/99	5.9	1.4	2.4	0.6	8.3	2.0	10.3	0.8	1.0	1.8
1999/00	6.1	1.5	2.7	0.6	8.7	2.1	10.8	0.9	0.9	1.7
2000/01	5.9	1.4	2.5	0.6	8.4	2.0	10.5	0.9	1.6	2.5
2001/02	6.0	1.4	2.7	0.6	8.6	2.1	10.7	0.9	2.0	2.9
2002/03	6.0	1.4	2.7	0.6	8.6	2.1	10.7	0.9	4.3	5.2
2003/04	6.1	1.5	2.3	0.6	8.4	2.0	10.4	0.9	6.1	7.0
2004/05	6.1	1.5	2.3	0.6	8.4	2.0	10.5	0.9	7.3	8.2
2005/06	6.3	1.5	2.4	0.6	8.6	2.1	10.7	0.9	9.5	10.4
2006/07	6.3	1.5	2.7	0.6	9.0	2.2	11.1	0.9	13.2	14.1
2007/08	6.1	1.5	2.7	0.6	8.8	2.1	10.9	0.9	20.5	21.4
2008/09	5.7	1.4	2.7	0.7	8.4	2.0	10.4	0.9	25.6	26.5
2009/10[1]	5.9	1.4	2.8	0.7	8.7	2.1	10.8	0.9	32.0	32.9
2010/11[1]	6.1	1.5	2.9	0.7	9.0	2.2	11.1	0.9	33.2	34.1

HFCS=High fructose corn syrup.
[1]Based on September 10, 2010, *World Agricultural Supply and Demand Estimates*.
Source: Data for corn dry-mill plants from table 1 of this report; data for corn wet-mill plants from table 2 of this report.

Table 5
Supply and disappearance of corn gluten feed

| Marketing year | Supply | | | | | Disappearance | | | | |
| | Production | | Imports | | Total | Feed and residual | | Exports | | Total |
	Million metric tons	Percent of total supply	Million metric tons	Percent of total supply	Million metric tons	Million metric tons	Percent of total disappearance	Million metric tons	Percent of total disappearance	Million metric tons
1992/93	6.5	98.4	0.11	1.6	6.7	0.9	14.0	5.7	86.0	6.7
1993/94	6.7	98.6	0.10	1.4	6.8	1.1	16.6	5.7	83.4	6.8
1994/95	7.7	98.9	0.08	1.1	7.8	1.6	20.3	6.2	79.7	7.8
1995/96	7.6	98.8	0.10	1.2	7.7	2.2	28.3	5.5	71.7	7.7
1996/97	7.8	98.8	0.10	1.2	7.9	2.7	33.8	5.2	66.2	7.9
1997/98	8.2	99.1	0.07	0.9	8.2	3.3	39.9	4.9	60.1	8.2
1998/99	8.3	99.8	0.02	0.2	8.3	3.3	40.2	5.0	59.8	8.3
1999/00	8.7	99.8	0.02	0.2	8.8	3.6	41.2	5.1	58.8	8.8
2000/01	8.4	99.8	0.02	0.2	8.5	3.8	45.1	4.6	54.9	8.5
2001/02	8.6	99.8	0.02	0.2	8.6	4.1	47.0	4.6	53.0	8.6
2002/03	8.6	99.6	0.03	0.4	8.7	4.9	56.6	3.8	43.4	8.7
2003/04	8.4	99.5	0.05	0.5	8.5	4.9	58.4	3.5	41.6	8.5
2004/05	8.4	99.6	0.03	0.4	8.5	5.7	67.1	2.8	32.9	8.5
2005/06	8.6	99.6	0.03	0.4	8.7	6.0	68.7	2.7	31.3	8.7
2006/07	9.0	99.7	0.03	0.3	9.0	7.4	81.9	1.6	18.1	9.0
2007/08	8.8	99.4	0.05	0.6	8.8	7.4	83.6	1.4	16.4	8.8
2008/09	8.4	99.4	0.05	0.6	8.5	7.6	89.4	0.9	10.6	8.5
2009/10	8.7	99.4	0.05	0.6	8.8	7.9	89.7	0.9	10.3	8.8
2010/11	9.0	99.4	0.05	0.6	9.1	8.2	90.1	0.9	9.9	9.1

Source: Production numbers are from table 4 of this report; import and export data from U.S. Department of Commerce (b), Census Bureau, http://www.usatradeonline.gov/.

Table 6
Supply and disappearance of corn gluten meal

| Marketing year | Supply | | | | | Disappearance | | | | |
| | Production | | Imports | | Total | Feed and residual | | Exports | | Total |
	Million metric tons	Percent of total supply	Million metric tons	Percent of total supply	Million metric tons	Million metric tons	Percent of total disappearance	Million metric tons	Percent of total disappearance	Million metric tons
1992/93	1.6	99.7	0.00	0.3	1.6	1.0	64.5	0.6	35.5	1.6
1993/94	1.6	99.6	0.01	0.4	1.6	0.9	54.4	0.7	45.6	1.6
1994/95	1.9	99.5	0.01	0.5	1.9	1.2	66.2	0.6	33.8	1.9
1995/96	1.8	99.2	0.01	0.8	1.8	1.1	57.9	0.8	42.1	1.8
1996/97	1.9	99.3	0.01	0.7	1.9	1.1	58.8	0.8	41.2	1.9
1997/98	2.0	99.4	0.01	0.6	2.0	1.2	61.1	0.8	38.9	2.0
1998/99	2.0	99.4	0.01	0.6	2.0	1.4	67.8	0.6	32.2	2.0
1999/00	2.1	99.4	0.01	0.6	2.1	1.4	67.1	0.7	32.9	2.1
2000/01	2.0	99.5	0.01	0.5	2.0	1.2	61.2	0.8	38.8	2.0
2001/02	2.1	99.3	0.01	0.7	2.1	1.3	60.7	0.8	39.3	2.1
2002/03	2.1	99.3	0.01	0.7	2.1	1.3	61.0	0.8	39.0	2.1
2003/04	2.0	99.4	0.01	0.6	2.0	1.1	55.6	0.9	44.4	2.0
2004/05	2.0	99.5	0.01	0.5	2.0	1.2	57.7	0.9	42.3	2.0
2005/06	2.1	99.4	0.01	0.6	2.1	1.2	56.8	0.9	43.2	2.1
2006/07	2.2	99.5	0.01	0.5	2.2	1.2	54.3	1.0	45.7	2.2
2007/08	2.1	99.4	0.01	0.6	2.1	1.0	48.2	1.1	51.8	2.1
2008/09	2.0	99.6	0.01	0.4	2.0	1.3	65.5	0.7	34.5	2.0
2009/10	2.1	99.5	0.01	0.5	2.1	1.4	66.8	0.7	33.2	2.1
2010/11	2.2	99.5	0.01	0.5	2.2	1.5	68.3	0.7	31.7	2.2

Source: Production numbers are from table 4 of this report; import and export data from U.S. Department of Commerce (b), Census Bureau, http://www.usatradeonline.gov/.

Composition of Distillers' Grains Is Beginning to Change

In addition to the switch from wet to dry milling, new technologies and production processes are changing the composition of distillers' grains. When the ethanol boom started in the mid-2000s, essentially all additional capacity expansion came from dry-mill ethanol plants. These plants required less capital to build, and investors at the time were interested primarily in ethanol since its margins were more attractive (Randleman and Shapouri, 2007). Consequently, fewer investors were interested in the potential coproduct revenue stream. With time, however, ethanol margins tightened and ethanol plant operators looked for additional revenue from their coproducts by improving the quality and consistency of DDGS. Potential coproducts include carbon dioxide and, more recently, corn oil.[13] As processors extract as much value from the corn as possible, future spent grains from ethanol production could be used as an alternative feedstock for cellulosic ethanol, fuel for the distillation process or electricity generation, or with anaerobic digestion, assuming profitability supports this feedstock selection.

Presently, there are two dry-mill fractionation processes that can alter the composition of distillers' grains. The first process can be and has been added to the front end of dry-mill ethanol plants.[14] This process can be a wet or dry process and can produce bran, germ (whole or defatted germ meal), and various combinations of these prefermentation byproducts. For example, adding germ to the bran produces "high fat hominy." Separation of the germ (fat-rich portion of the corn kernel) and the high fiber bran from the endosperm prior to fermentation results in stillage that is lower in fiber, fat, and phosphorus and higher in protein than traditional distillers' grains (Onetti and Schwab, 2008). The starch content of these prefermentation byproducts also varies significantly, depending on the effectiveness of the different milling processes in separating the endosperm from the other kernel components prior to fermentation.

The second fractionation process, commonly called back-end, is a less costly endeavor than the front-end process and is rapidly gaining more widespread usage in the ethanol industry. The back-end process extracts corn oil from either stillage or CDS. Generally, the oil content found in DDGS is about 11.2 percent and can be reduced by a third to 7.5 percent. A more expensive technology, however, can remove from two-thirds to three-quarters of the oil, resulting in 3.7 percent to 2.8 percent oil content.

Generally, many of these new corn coproducts are higher in crude protein and crude fiber than "regular" DDGS and lower in crude fat. Although the amino acid concentration may increase somewhat in many of these high-protein coproducts, the protein quality (amino acid balance) is still poor relative to the requirements of monogastric animals.[15] Additionally, the reduced fat and increased fiber content of these new coproducts may provide lower energy value for swine and poultry (Shurson and Alghandi, 2008). Thus, the feeding and economic value of these "reduced fat" DDGS may be lower for swine and poultry, compared with "regular" DDGS. The nutrient composition of these coproducts, however, would likely have greater value in ruminant diets because the amino acid balance of corn protein is not as critical for ruminants

[13] Some plants already capture the carbon dioxide and others have started. One challenge for the industry is finding a market for the carbon dioxide collected (Rendleman and Shapouri, 2007).

[14] Currently, there are only two or three plants using front-end fractionation due to costs and complications from production and marketing multiple coproducts (Staff, 2010).

[15] A monogastric organism has a simple single-chambered stomach, whereas ruminants have a complex four-chambered stomach. Examples of monogastric animals include pigs, dogs, and cats. Poultry also have a monogastric digestive system.

as it is for swine and poultry. The increased amount of readily digestible fiber can provide a good source of energy, and the lower fat content may allow higher dietary inclusion rates for lactating dairy cows, avoiding milk-fat depression concerns. Until further evidence is provided, animal nutritionists have cautioned feeders about these new coproducts since the number of published studies evaluating them in livestock and poultry diets has been limited (Shurson and Alghamdi, 2008).

Growth of U.S. Distillers' Grains Supply Expected to Moderate

The U.S. Department of Agriculture projects that 5.0 billion bushels of corn will be used in fuel ethanol production in 2019/20 (USDA, February 2010), up from the 4.5 billion bushels projected for 2009/10 (USDA, September 2010). Slower annual growth for corn-based ethanol is projected, following the rapid expansion seen in recent years.[16] Consequently, the supply of distillers' grains is estimated to rise from about 33.3 mmt in 2009/10 to about 38.6 mmt in 2019/20.[17, 18] Whether this projected production estimate represents a saturation of the feed market will be discussed later.

[16] Smaller gains for corn-based ethanol are projected over the next 10 years and reflect only moderate growth in overall gasoline consumption in the United States, limited potential for further market penetration of ethanol into the E10 (10-percent ethanol blend) market (the blend wall), and the small size of the E85 (85-percent ethanol blend) market. In the latter years of the projections, production of fuel ethanol accounts for 34-35 percent of total corn use, and corn-based ethanol production exceeds 9 percent of annual gasoline consumption.

[17] Assumes 1 mmt of DDGS comes from beverage distilleries, 0.5 mmt is imported and ((5.025 billion bushels x 93 percent dry-mill grind) x 17.5 pounds of DDGS per bushel of corn processed) / 2204.622 pounds per metric ton = 38.6 mmt supply.

[18] If we assume that 15 billion gallons of corn-based ethanol will be produced in 2019/20, corn use for this dry-mill fuel ethanol could total 5.17 billion bushels (2.7 gallons ethanol per bushel of corn and 93 percent of ethanol produced from dry-mill plants), which would produce about 41.0 mmt plus 1 mmt from beverage distilleries, and .5 mmt from imports = about 42.5 mmt supply.

Consumption of Distillers' Grains Increases, Export Share Expands

The estimated disappearance of U.S. distillers' grains is expected to total 33.3 mmt for 2009/10, more than doubling since 2006/07 (see table 1). U.S. feed and residual use accounts for the largest share of consumption of U.S. distillers' grains. Domestic feeders have been rapidly adopting this product to take advantage of its nutrient and cost advantages. Despite the many issues of product quality, consistency, handling, and feed safety, DDGS provide good value per unit of energy and protein. Despite increased feeding of DDGS by domestic feeders, the rate of growth for exports exceeds the rate of growth in domestic use. Between marketing years 2003/04 and 2009/10, the domestic use share has dropped by 15 percentage points, with an offsetting increase in export share of U.S. distillers' grains disappearance.

Export share is increasing as foreign feeders adopt DDGS as a cheaper alternative to corn and U.S. trade groups work to alleviate concerns over product quality, consistency, and safety (Voegele, 2009).[19, 20] While the European Union had been the largest importer of U.S. distillers' grains through 2005/06, CAP reform and biotechnology regulations have significantly reduced the quantity of U.S. exports to the EU market.[21] Since then, Mexico has become the largest importer of U.S. distillers' grains, followed by Canada and Asian countries (table 7) (Fox, 2008 and 2009; Paulson, 2008). The potential for increased exports to China appears promising (Fabiosa et al., 2009). For the 2009/10 marketing year, DDGS exports to China have been expanding and China could become the largest importer of U.S. distillers' grains. The imported Chinese DDGS price, relative to domestic Chinese corn prices or imported corn prices, appears to be the primary driver of DDGS imports into China for marketing year 2009/10. The availability of shipping containers, providing a "backhaul" opportunity, has facilitated the movement of this product relative to shipping in larger bulk ocean vessels.

Future consumption growth of DDGS is expected to moderate with a declining domestic share and rising export share (USDA, February 2010). The domestic share of the projected supply could range from 70 to 75 percent, with the export share ranging from 25 to 30 percent, compared with the 2009/10 estimated domestic share of 75 percent and export share of 25 percent.

[19] The U.S. Grains Council supports an active research/demonstration program of the benefits of feeding distillers' grains and reports success in many of its demonstration countries. Furthermore, they estimate a potential 20 mmt of DDGS exports from the United States, indicating significant growth potential.

[20] Despite some insurance companies insisting that DDGS be treated as hazardous cargo, DDGS exports have grown rapidly in the past several years. As a result of DDGS' status as hazardous cargo, there have been some shipping disruptions and higher transport costs for DDGS exports. The U.S. Grains Council was instrumental in coordinating an industry effort to define DDGS as nonhazardous cargo. These efforts, in cooperation with the U.S. Coast Guard led to a U.S. proposal that was submitted to the International Maritime Organization (IMO). A subcommittee of the IMO approved the U.S. proposal to classify DDGS as nonhazardous cargo, but the proposal must be ratified by the IMO's Maritime Safety Committee. Industry experts expect this to occur during the committee's December 2010 meeting (U.S. Grains Council, 2010).

[21] Although the EU could increase its imports of DDGS with the approval of three types of genetically enhanced corn for food, feed, import, and processing as of October 30, 2009, this potential could be replaced with DDGS from fuel ethanol plants being built in Great Britain, Europe, and Africa (U.S. Grains Council, 2009).

Table 7
Exports of U.S. brewers' or distillers' dregs and waste, by crop year

Area	Importing country	Crop year							
		1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00
		--Metric tons--							
North America	Canada	16,002	14,675	16,121	11,483	16,747	14,248	18,522	13,605
	Mexico	20,239	40,823	26,714	4,326	8,433	11,932	17,682	28,822
Total		36,241	55,498	42,835	15,809	25,180	26,180	36,204	42,427
Caribbean	Cuba								
Asia	Japan	219	1,246	1,544	20		5,014	877	1,466
	China-Taiwan	2,285			70	42	492	57	80
	South Korea	485	1,857		14,400				
	China-Mainland		497			57			
	Philippines								
	Indonesia								
	Malaysia	46	254						
	Vietnam								
	Thailand								62
Total		3,035	3,854	1,544	14,490	99	5,506	934	1,608
Middle East and North Africa	Turkey								
	Israel			9,096	28,269		5,506		2,786
	Egypt								
	Morocco								
Total				9,096	28,269				2,786
European Union	Denmark	447	2,968	35,664	72,584	137,720	120,627	139,877	115,719
	United Kingdom	9,432	7,014	58,570	59,638	119,327	86,588	86,584	87,489
	Ireland	36,645	64,454	179,295	166,471	156,027	146,708	218,828	241,743
	Netherlands	8,648	9,824	65,928	30,122	45,377	15,495	27,777	2,929
	France	3,836	6,994	71,907	43,952	36,203	31,990	35,864	24,447
	Germany	2,565			4,337		973		29,847
	Spain	6,636	6,257	104,436	73,163	36,902	52,890	78,110	72,311
	Portugal	19,983	20,352	113,669	117,549	85,221	90,160	79,833	97,122
	Italy		750	55,259	19,533	28,857	24,680	16,064	12,746
Total		88,192	118,613	684,728	587,349	645,634	570,111	682,937	684,353
Subtotal		127,468	177,965	738,203	645,917	670,913	601,797	720,075	731,174
Other countries		714	1,404	2,519	317	748	3,002	43	44,668
Total		128,182	179,369	740,722	646,234	671,661	604,799	720,118	775,842

continued

Table 7
Exports of U.S. brewers' or distillers' dregs and waste, by crop year, *continued*

Area	Importing country	2000/01	2001/02	2002/03	2003/04	Crop year 2004/05	2005/06	2006/07	2007/08	2008/09
						---- Metric tons ----				
North America	Canada	26,325	26,864	32,931	46,689	116,633	113,895	190,373	683,361	704,451
	Mexico	41,105	27,895	41,325	59,374	92,500	280,602	607,848	1,000,936	1,387,153
Total		67,430	54,759	74,256	106,063	209,133	394,497	798,221	1,684,297	2,091,604
Caribbean	Cuba						10,043	40,646	112,489	146,468
Asia	Japan	26	40	15		288	29,039	78,523	151,243	210,517
	China-Taiwan				3,732	29,227	73,126	126,272	172,530	181,393
	South Korea		14	50	106	2,111	11,497	87,730	175,515	279,622
	China-Mainland			18	42	54		1,150	4,593	97,936
	Philippines		51		377	5,374	49,210	67,349	95,896	127,618
	Indonesia				3,160	36,744	45,860	63,790	90,624	182,712
	Malaysia				7,097	24,614	33,682	32,141	53,687	47,009
	Vietnam				633	13,093	12,645	47,993	101,332	183,966
	Thailand			61	10	5,102	26,290	50,561	130,354	270,488
Total		26	105	144	15,157	116,607	281,349	555,509	975,774	1,581,261
Middle East and North Africa	Turkey					216	416	17,600	403,128	380,176
	Israel			6,032	6,348	45,694	8,607	40,256	167,379	176,982
	Egypt								31,308	67,843
	Morocco						20,254	37,318	68,705	74,450
Total				6,032	6,348	45,910	29,277	95,174	670,520	699,451
European Union	Denmark	140,497	130,287	88,856	20,539	117		660		
	United Kingdom	64,962	117,434	141,287	194,731	116,935	152,087	79,894	16,960	6,229
	Ireland	270,936	258,611	285,093	203,316	204,195	186,897	66,377	79,605	95,816
	Netherlands	30,326	10,295	15,943	35,109	54,344	9,014	18,690	18,846	
	France	5,659	3,000				1,121			
	Germany	31,442	30,920	580	5,144	26,213	9,749			
	Spain	30,699	85,310	37,380	61,184	90,836	68,455	26,267	49,698	14,999
	Portugal	76,896	67,498	61,315	58,547	68,848	50,038	8,054		
	Italy		22,032						384	
Total		651,417	725,387	630,454	578,570	561,488	477,361	199,942	165,493	117,044
Subtotal		718,873	780,251	710,886	706,138	933,138	1,192,527	1,689,492	3,608,573	4,635,828
Other countries		63,628	75,640	41,350	31,727	34,250	36,808	90,386	312,090	325,170
Total		782,501	855,891	752,236	737,865	967,388	1,229,335	1,779,878	3,920,663	4,960,998

Source: U.S. Department of Commerce (b), Bureau of the Census. http://www.usatrade online.gov/.

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Potential U.S. Feed Consumption Exceeds Future Supply of DDGS

Industry experts were concerned that the rapid acceleration of ethanol production could cause the supply of distillers' grains to exceed its potential use in the feed market. If this is the case, the feed market and other potential uses of DDGS, such as boiler fuel or soil amendments, could be affected. The authors of this report project that the future U.S. DDGS supply will be 38.6 mmt in 2019/20 based on USDA's Baseline Projections (USDA, February 2010). Selected estimates of current potential U.S. DDGS feed consumption range from 35.2 to 55.3 mmt (Dhuyvetter et al., 2005; Berger and Good, 2007; Dooley, 2008; Fox, 2008) (table 8). Thus, projected DDGS supplies do not appear to exceed the estimated average potential of 46.7 mmt for the domestic feed market.

Furthermore, potential exports of DDGS range from 20 mmt to 52 mmt. The U.S. Grains Council reports that the export market shows current potential use at 20 mmt (Keefe, 2008). Another estimate for potential export consumption comes in at 52 mmt. For example, Fox (2008) estimated 12 mmt for large international markets and Paulson (2008) estimated 40 mmt for small international markets. So, there appears to be sufficient use potential in both the U.S. and export feed market to consume the U.S. distillers' grain supply, assuming DDGS prices remain favorable for feeding.

Table 8

Estimates of potential annual DDGS consumption, by livestock class

	Dhuyvetter et al. 2000-2004 average[1]		Berger and Good 2007[1]		Dooley 2008[1]		Fox 2008[1]		Average of all estimates	
	Thousand metric tons	*Percent*	*Thousand metric tons*	*Percent*	*Thousand metric tons*	*Percent*	*Thousand metric tons*	*Percent*	*Thousand metric tons*	*Percent*
Beef cattle	29,446	63.1	38,709	70.0	34,524	69.1	20,774	59.1	30,863	65.4
Beef cows	9,803	21.0	10,859	19.7	5,703	11.4	4,807	13.7	7,793	16.4
Cattle on feed	12,261	26.3	15,450	28.0	16,591	33.2	12,761	36.3	14,266	30.9
Other cattle	7,381	15.8	12,400	22.4	12,230	24.5	3,206	9.1	8,804	18.0
Dairy cattle	6,276	13.5	6,779	12.3	5,347	10.7	7,693	21.9	6,524	14.6
Dairy cows	6,276	13.5	6,779	12.3	5,347	10.7	7,693	21.9	6,524	14.6
Swine	3,663	7.9	3,824	6.9	3,842	7.7	3,677	10.5	3,752	8.2
Breeding swine	1,037	2.2	1,031	1.9	973	1.9	642	1.8	921	2.0
Market swine	2,626	5.6	2,793	5.1	2,869	5.7	3,035	8.6	2,831	6.3
Poultry	7,245	15.5	5,950	10.8	6,215	12.4	3,014	8.6	5,606	11.8
Broilers	4,486	9.6	4,263	7.7	3,709	7.4	1,809	5.1	3,567	7.5
Layers	1,818	3.9	1,686	3.1	1,644	3.3	683	1.9	1,458	3.0
Pullets	161	0.3			104	0.2			133	0.1
Turkeys	780	1.7			757	1.5	522	1.5	686	1.2
Total	46,630	100.0	55,261	100.0	49,929	100.0	35,158	100.0	46,744	100.0

Note: Totals may not add due to rounding.

[1] Calendar year.

Source: Dhuyvetter et al., 2005; Berger and Good, 2007; Dooley, 2008; Fox 2008.

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Both domestic and export consumption estimates are derived from a fairly uniform method. Daily intake (as fed) per species is established and multiplied by the DDGS typical inclusion rate, multiplied by days fed per year, multiplied by the annual head (based on whether it is an annual inventory number or annual number produced) of selected beef cattle, dairy cattle, swine, and poultry. Summing for each type of livestock provides an estimation of the potential DDGS consumption level for the particular country in question. If any of these variables differ, then potential consumption estimates will also differ. For example, if inventory numbers rise or decline, the industry could generally expect potential DDGS consumption to respond accordingly. Estimates of daily intake and inclusion rates also differ by study, which accounts for some of the variance in potential consumption estimates. Also, some of the studies use a multi-year average estimate of livestock inventories, while others may use inventories from a specific year.

Potential consumption estimates derived from each of the referenced studies assume that DDGS were priced competitively and would enter the livestock/poultry ration. There may be times when feed use of DDGS is curtailed or discontinued because of unfavorable prices for DDGS relative to competing ration ingredients. Also, there may be times when livestock/poultry producers switch from a typical inclusion rate of DDGS to a maximum inclusion rate because of more favorable DDGS prices relative to competing ingredient prices. Thus, changing the prices for livestock/poultry ration's competing ingredients could impact the estimated feed potential of DDGS.

In addition to market prices, the adoption of new ethanol/DDGS production technologies can influence the relationship between DDGS supply and its potential use. As the composition of DDGS (such as the removal of a portion of the oil) changes, then the use of DDGS for different types of livestock might change.

Price Discovery, Risk Management, and Price Relationships

The surge in ethanol production creates a question about the relationships between DDGS, corn, and soybean meal prices and how they may change.[22] Many grain prices are simultaneously determined by a futures market price and the cash market. Nearly half of the respondents to a recent survey stated that a distillers' grain futures contract would be an important risk management tool (Stroade et al., 2010).[23] A futures market for DDGS, however, did not exist until very recently.[24] We used a basic approach to analyze the price relationships among DDGS, corn, and soybean meal, indicating other areas of potential research as the market for DDGS develops.

Price Discovery and Risk Management

Very little scholarly research has been conducted on price discovery for the DDGS market. Stroade et al. attempted to address some of the price discovery and risk management questions for DDGS. Their survey results indicated that ethanol plants establish DDGS transaction prices based on corn futures prices (87 percent of respondents), soybean meal prices (43 percent of respondents), other sources (23 percent of the respondents), USDA published DDGS prices (16 percent of respondents), and no external sources (3 percent of the respondents). Slightly more than 40 percent of the respondents used multiple sources of information to price their DDGS.

The survey asked two questions about DDGS price risk management. The first question asked about the methods used to manage price risk management. A majority of the respondents used a price risk management method (64 percent of the respondents), while 36 percent stated they did nothing to manage price risk for DDGS. The second question asked about the methods used to manage DDGS price risk. For those using a price risk management method, corn futures prices (45 percent of the respondents) and forward contracts (40 percent of the respondents) were the price risk methods most reported. About 20 percent of the respondents used both corn futures and forward contracts. Only one respondent reported using soybean meal futures.

Schroeder (2009) found that DDGS prices are not effectively cross hedged based on traditional corn or soybean meal futures prices. Furthermore, Schroeder states that since there is no effective cross-hedging potential between DDGS prices and corn or soybean meal futures prices, a futures market for DDGS should be investigated. The corn distillers' dried grain futures contract, which began on April 26, 2010, is expected to bring much needed price discovery tools and price transparency to the market, but will also serve as a risk management tool for ethanol plants and livestock/poultry feeders. Actual trading of the contract over time will determine its success.

[22] Initially, a useable price series was a problem, but a Central Illinois (later referred to as Eastern Corn Belt) price series was found and used (USDA, *Corn Belt Weekly Feedstuffs*, 2010). These data are available for every Tuesday from May 1995 to the present. Later, USDA's Agricultural Marketing Service began providing weekly DDGS prices for different markets, such as Iowa, Wisconsin, Minnesota, Missouri, and Nebraska. USDA's Agricultural Marketing Service also began providing ethanol plant reports that covered the price of corn, distillers' grains (DDGS, MDGS, and WDGS), and ethanol (USDA, AMS, *Bioenergy Market News* report, 2010; USDA, "National Weekly Distillers' Grain Summary," 2010; USDA, "National Weekly Ethanol Summay," 2010) Corn and soybean meal prices for Central Illinois were obtained from USDA, ERS, Feed Grains Database.

[23] Information presented in the price discovery and price risk management sections are based on a 2010 survey by Stroade, Martin, Conrad, and Schroeder of ethanol plants listed by the Renewable Fuels Association.

[24] On February 16, 2010, the CME Group announced a new futures contract for DDGS. Trading began on April 26, 2010 and contract specification information can be found at http://www.cmegroup.com.

DDGS Price Relationship with Corn and Soybean Meal

Monthly DDGS prices (dry matter basis) for Central Illinois (fig. 1) ran at a premium to the corn price, with an average ratio of 1.09 for May 1995 to August 2006 (fig. 2). Beginning with marketing year 2006/07, however, monthly DDGS prices have averaged less than corn prices. The price ratio averaged 0.89 for September 2006 to August 2010 and ranged between 0.70 to 1.02. Thus, DDGS prices are falling into a range where they become more competitive as a feed source for many livestock and poultry rations.[25] The general decline in DDGS prices relative to corn (May 1995 to August 2006 compared with September 2006 to July 2010) is due, in part, to increased DDGS production. The increased seasonality within the marketing year also may be influencing the monthly price ratio. DDGS prices are higher in the winter months when pasture is not available, and then prices decline in the spring and summer as more pasture and forage become available. This is particularly interesting considering that there is an increase in DDGS consumption by beef cattle.

Monthly price ratios of DDGS to soybean meal (dry matter basis) averaged 0.49 for May 1995 to August 2006, compared with 0.44 for September 2006 to August 2010 (fig. 2). These price ratios are consistent with DDGS' status as a medium-protein feed, but the slight decline in the DDGS/soybean meal price ratio relative to DDGS/corn price ratio reflects DDGS' increased production and lower price. The increased DDGS supply, accompanied by a lower price, leads to a lower DDGS price relative to corn (usually less than corn). DDGS also substitutes for soybean meal, which may reduce the

[25] Figure 2 highlights the fact that the first time period is much longer than the more recent period characterized by the surge in distillers' grain production. Thus, a degree of caution should be used while interpreting these differences.

Figure 1
Monthly prices: Soybean, DDGS, and corn, May 1995-August 2010

Dollars per ton
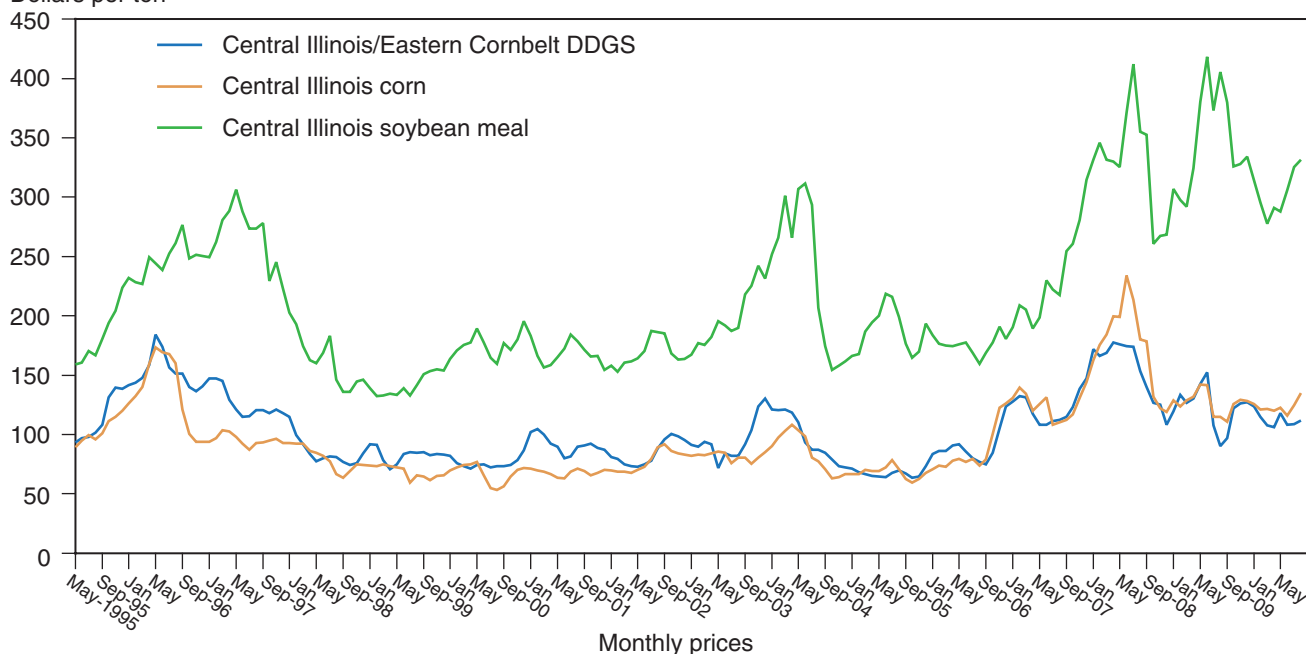
Monthly prices

Note: Monthly prices for September-August marketing year.
Source: USDA, *Corn Belt Weekly Feedstuffs*; Missouri Department of Agriculture News Service, St. Joseph, Missouri,
http://ams.usda.gov/mnreports/sj_gr225.txt; USDA, Economic Research Service, Feed Grains Database.

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Figure 2
Monthly price ratios (dry matter basis): DDGS compared with corn and soybean meal, May 1995-August 2010
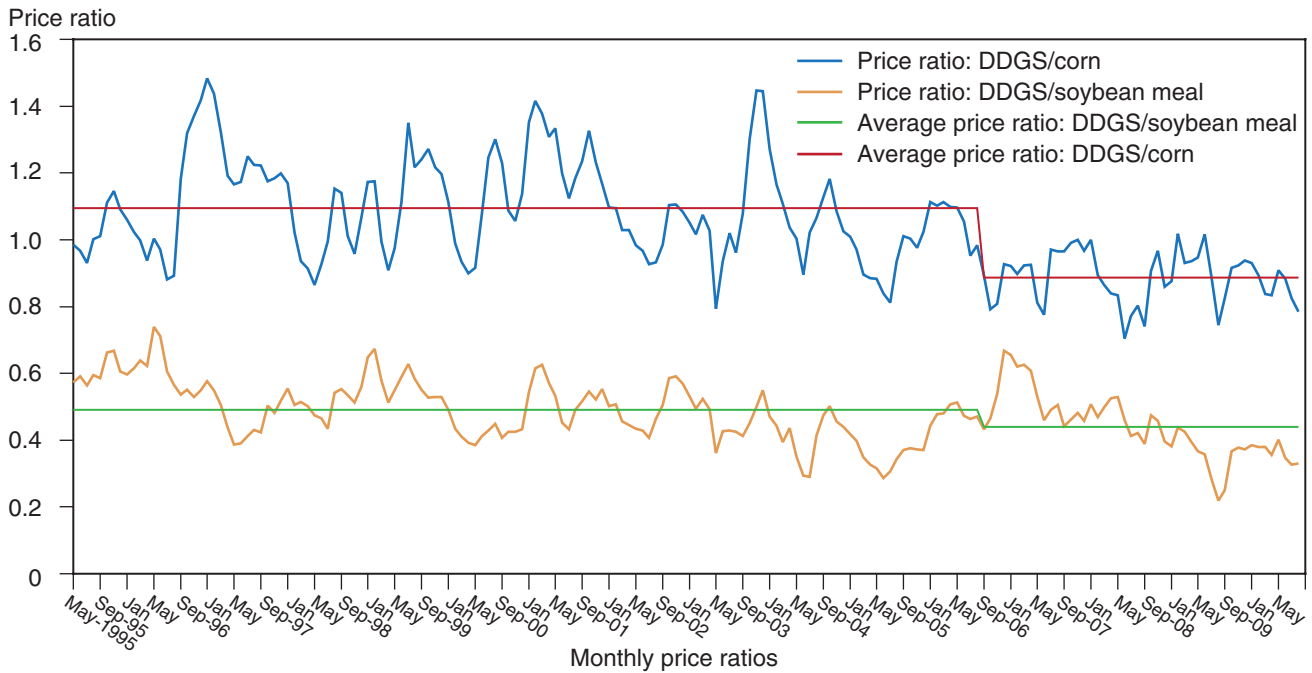
Price ratio

Monthly price ratios

Note: Monthly prices for September-August marketing year.
Source: USDA, *Corn Belt Weekly Feedstuffs*; Missouri Department of Agriculture News Service, St. Joseph, Missouri, http://ams.usda.gov/mnreports/sj_gr225.txt; USDA, Economic Research Service, Feed Grains Database.

demand and price for soybean meal, but a sharper drop in the price of DDGS is reflected in a decline of the DDGS/soybean meal price ratio.

A simple model of DDGS prices was estimated using two major feed components that are replaced by DDGS—corn (energy) and soybean meal (protein). Corn and soybean meal prices accounted for 98 percent of the variation in DDGS prices and thus are major determinants of the DDGS price (see equation 1 in box, "Major Determinants for the Price of DDGS are Corn and Soybean Meal Prices," p. 23). But the real issue is whether these relationships have changed with the surge in dry-mill ethanol production. We can now model how these relationships held with the surge in dry-mill ethanol production. As seen in equation 2 compared with equation 1, DDGS are increasingly used as an energy feed and, as a result, soybean meal prices may be starting to lose some of their impact on DDGS prices, as the coefficient value for soybean meal declined to less than half that reported in equation 1. The statistical significance of soybean meal prices as an explanatory variable for DDGS prices also declined slightly. An increase in cattle feeding, and, thus an increase in the seasonality of DDGS prices, may also contribute to the decline in the coefficient value for soybean meal prices. Further analysis should explore the effects of seasonality on this price relationship.

As reported earlier, DDGS are viewed as a mid-protein feed ingredient, but they are also rich in energy. As a result of these characteristics, the price of DDGS usually runs above competing medium protein feeds, such as corn gluten feed, hominy feed, and wheat middlings (fig. 3).

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Figure 3
Monthly prices: DDGS and competing feed ingredients, May 1995-July 2010

Dollars per ton
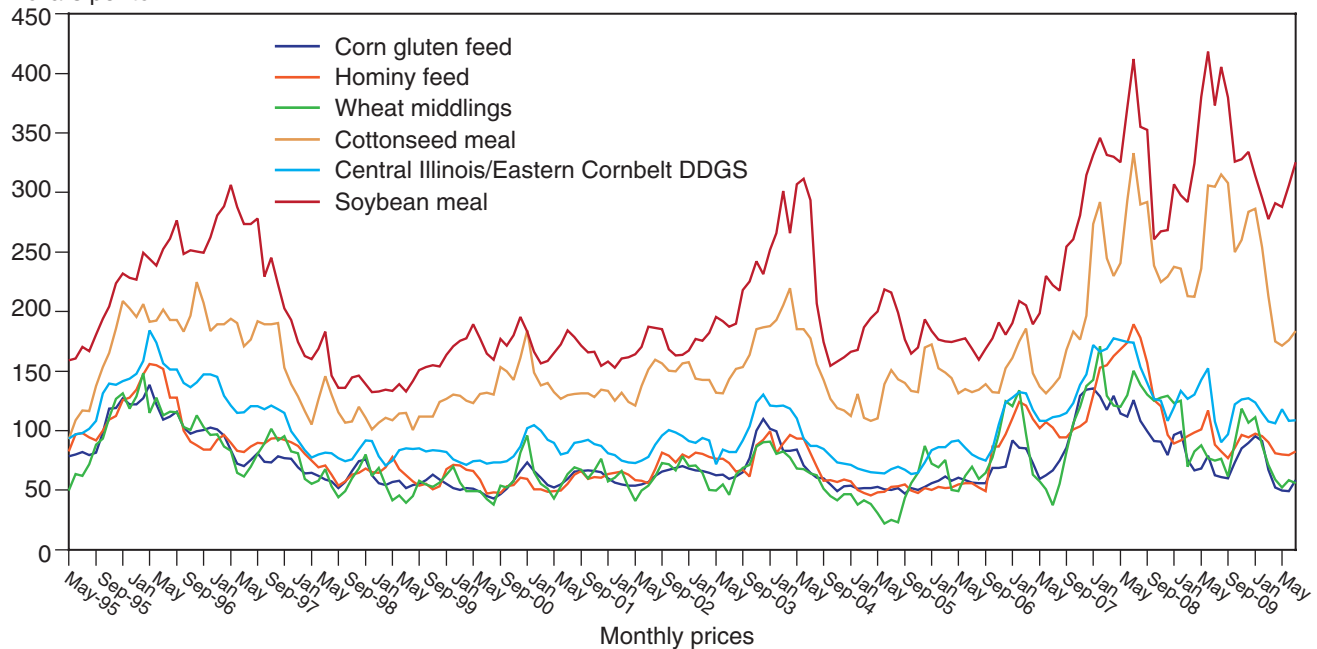
Monthly prices

Note: Monthly prices for September-August marketing year.
Source: USDA, *Corn Belt Weekly Feedstuffs*; Missouri Department of Agriculture News Service, St. Joseph, Missouri,
http://ams.usda.gov/mnreports/sj_gr225.txt; USDA, Economic Research Service, Feed Grains Database.

Regional DDGS Price Relationships

DDGS prices appear to be highly correlated among States and producers. The Pearson correlation coefficients of monthly DDGS prices among selected States (Central Illinois, Nebraska, Iowa, Minnesota, Kansas, and Missouri) for the most recent 3 marketing years (2006/07 through 2008/09) revealed that select State DDGS prices had a positive correlation with the coefficients near 0.90 or above (USDA, Corn Belt Weekly Feedstuffs).[26] DDGS price correlation coefficients for weekly DDGS prices over the same general time period at selected State ethanol plants as published by USDA's Agricultural Marketing Service (table 5) were also high, near 0.90 or above (USDA, AMS, *Bioenergy Market News* report). These findings suggest that DDGS prices across States and producers are highly correlated and move together. In contrast, Schroeder (2009) found that spatially separated DDGS markets do not have strong price relationships. His study focused, however, on the long term and included different markets with a time series beginning in 2001, when the market for DDGS was less mature. As DDGS production expands and DDGS are increasingly used as a substitute for corn and soybean meal in feed rations, prices should become more linked to corn and soybean meal prices. Corn and soybean meal prices are highly correlated among regions, with differences reflecting the cost of transportation and handling.

Increased feeding of beef cattle on the range and in the feedlot may increase DDGS demand during the late fall through winter months for Kansas and Nebraska as the DDGS to corn price ratio was highest during those months for 2007/08 and 2008/09 (fig. 4).[27] In the spring and summer, when pasture or forage is more available, DDGS prices tend to decline, exhibiting a degree

[26] In statistics, the Pearson product-moment correlation coefficient (referred to as PMCC and typically denoted by r) is a measure of the correlation (linear dependence) between two variables X and Y, giving a value between +1 and −1 inclusive. PMCC is widely used in the sciences as a measure of the strength of linear dependence between two variables.

[27] Corn prices are seasonally low at harvest, contributing to the higher ratio in the fall months.

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Major Determinants for the Price of DDGS are Corn and Soybean Meal Prices

Central Illinois DDGS price is a function of Central Illinois corn and soybean meal prices (all prices were converted to a dry matter basis). Using monthly prices for May 1995 through August 2006 (dollars per short ton)—a period prior to the surge in dry-mill ethanol production—we derived the following regression equation:

(1) DDGSpr = 0.77 cornpr   +   0.14 soymealpr   Adj. R^2 [1] = 98 percent[2]

$\qquad\qquad$ (0.05) $\qquad\qquad\qquad$ (0.02)

Where DDGSpr is the Central Illinois/Eastern Corn Belt price of DDGS, cornpr is the Central Illinois price of corn, and soymealpr is the Central Illinois price of soybean meal. Both corn and soybean meal prices are statistically significant at the 1 percent level.

Using monthly prices for September 2006 through July 2010 (dollars per short ton)—a period of increasing dry-mill ethanol production—we derived the following regression equation:

(2) DDGSpr = 0.77 cornpr   +   0.05 soymealpr   Adj. R^2 = 97 percent[2]

$\qquad\qquad$ (0.05) $\qquad\qquad\qquad$ (0.03)

Corn price is statistically significant at the 1 percent level, but the significance of the soybean meal price is at the 5 percent level.

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[1] The coefficient of determination, R^2, is the proportion of variability in a dataset (dependent variable) that is accounted for by the in-dependent variables in the statistical model. It provides a measure of how well future outcomes are likely to be predicted by the model. R-squared always increases when a new variable is added to a model. Sometimes additional variables are added to a statistical model simply to increase the R-squared. To compensate for this tendency, the adjusted R-squared is used. The adjusted R-square is a modifica-tion of R-squared that adjusts for the number of variables in a model. Adjusted R-squared increases only if the new variable improves the model more than would be expected by chance (see Peter Kennedy, *A Guide to Econometrics,* 1992).

[2] Numbers in parentheses below coefficient values are standard errors.

Figure 4

DDGS/corn price ratios (dry matter basis), by selected States, August 2006-July 2010

Price ratio of DDGS
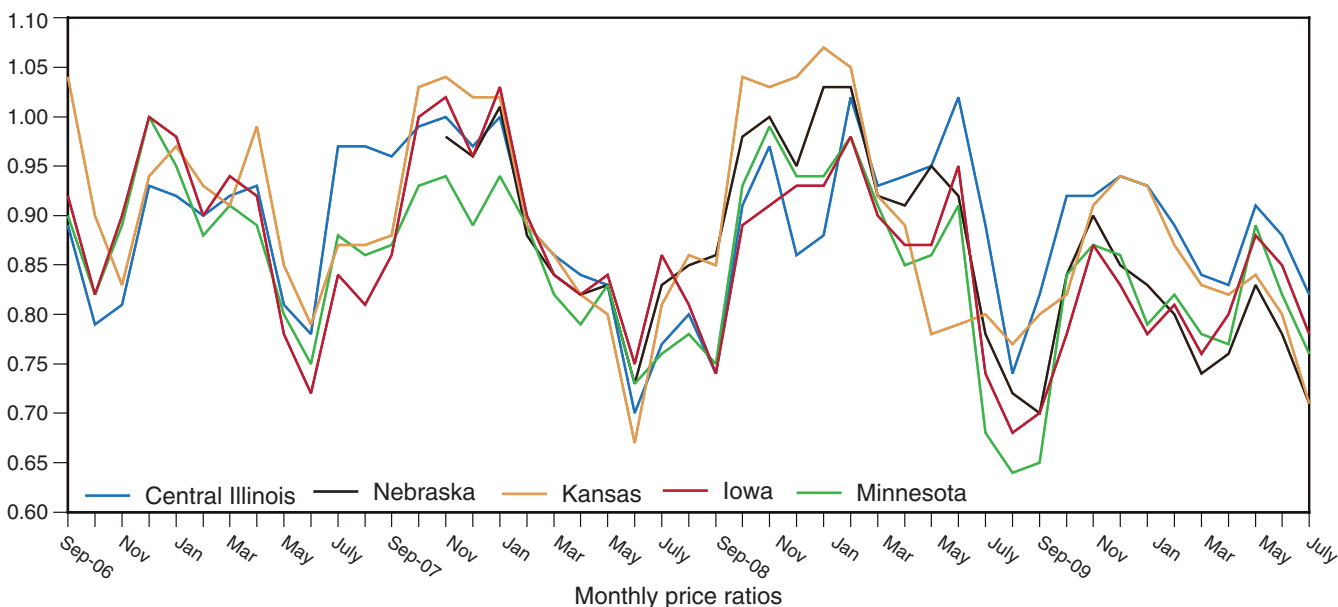
Monthly price ratios

Note: Monthly prices for September-August marketing year.
Source: USDA, *Corn Belt Weekly Feedstuffs*; Missouri Department of Agriculture News Service, St. Joseph, Missouri, http://ams.usda.gov/mnreports/sj_gr225.txt; USDA, Economic Research Service, Feed Grains Database.

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of the seasonality mentioned earlier. DDGS are a new feed for many users and optimizing their use in rations is an ongoing effort.

Price advantages of feeding distillers' grains (dry, modified, and wet) relative to corn are reflected in figure 5 for Illinois and figure 6 for Nebraska.[28] For November 9, 2007 through September 3, 2010, weekly Illinois ethanol plant prices of dry, modified, and wet distillers' grains relative to corn averaged 84, 66, and 37 percent, respectively (all dry matter comparisons) (fig. 5). Nebraska weekly ethanol plant prices of dry, modified, and wet distillers' grains (November 9, 2007 through September 3, 2010) relative to corn were 87, 72, and 41 percent, respectively (all dry matter comparisons) (fig. 6). Nebraska's price ratios were higher than for Illinois, likely due to Nebraska having a larger number of beef cattle relative to dairy cattle, hogs, or poultry.

The varying moisture content of distillers' grains could affect their potential in different markets in a particular State. Although WDGS had the lowest price of the three types of distillers' grains for Illinois and Nebraska, transportation, handling, and storage challenges seem to favor cattle feeding over swine and poultry. Wet and modified distillers' grains work best with beef-cattle rations, where higher percentages of the ration are possible.

The average DDGS prices for Illinois and Nebraska were favorable for feeding livestock/poultry during this time period, particularly for feeders located near ethanol plants. While the modified and wet distillers' grain prices averaged less than the corn price, there were handling and storage costs associated with these higher moisture feeds that must be considered by

[28] Prices are based on those reported at ethanol plants.

Figure 5
Weekly prices of corn and dry, modified, and wet distillers' grains (dry matter basis): Illinois ethanol plant, November 9, 2007-September 3, 2010
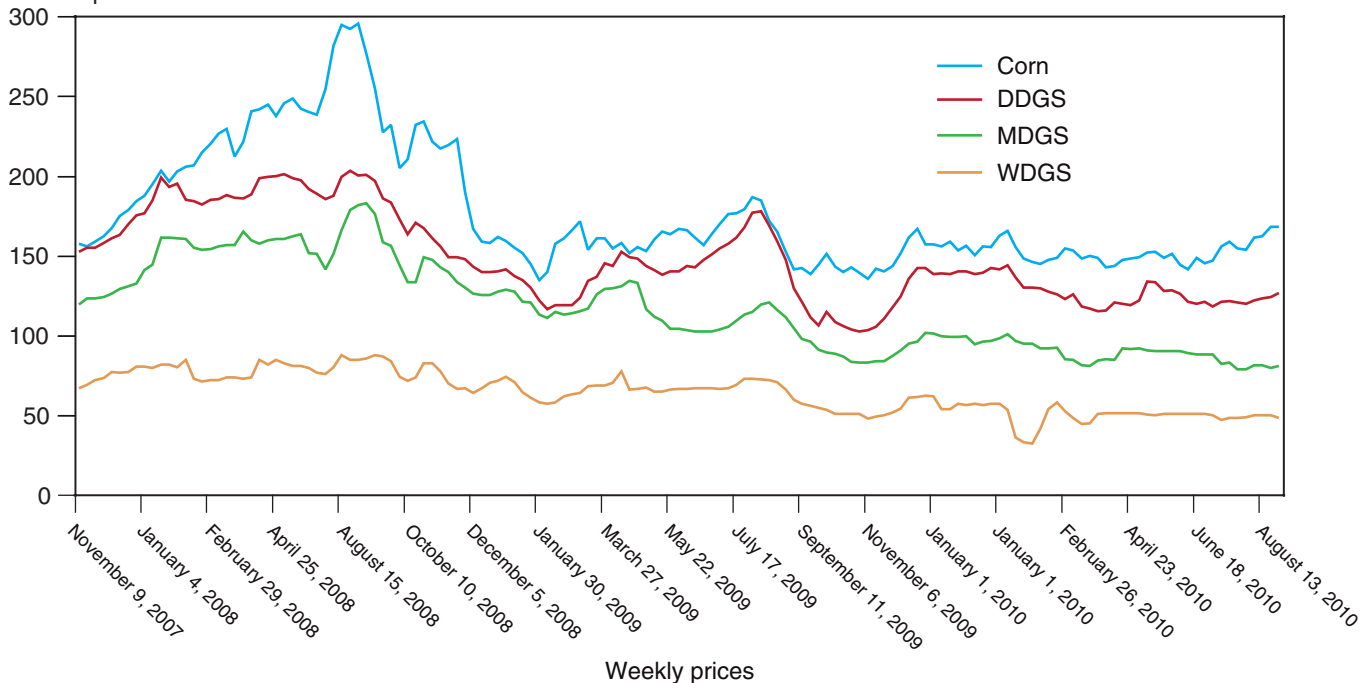
Note: Weekly prices for September-August marketing year.
Source: USDA, Agricultural Marketing Service, *Bioenergy Market News* reports.

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feeders. Feeders must also consider transportation costs for each product and the slightly higher energy levels for WDGS in cattle rations. Despite these averages, there are periods when DDGS and MDGS prices are nearly equal to each other for Illinois and Nebraska. The difference in these prices could reflect the cost of drying. Schroeder (2009) suggests that if the dry, modified, and wet distillers' grain markets are closely linked and efficient, the price differences on a dry-matter basis across these product forms would essentially equal the cost of drying. The price behavior of natural gas would have to be examined to see if it influenced this relationship. Also, demand factors may permit higher prices for DDGS than the cost of drying would suggest.

Corn and soybean meal prices are important determinants of the DDGS price and may explain why some DDGS producers rely on corn and soybean meal futures prices to establish DDGS prices, and why some use corn and soybean meal futures as a risk management tool. Average DDGS prices now run at a discount to corn compared with an average premium prior to the surge in distillers' grain production. Our statistical analysis indicates that soybean meal prices are losing some of their explanatory power for DDGS prices, suggesting that DDGS are increasingly being used as an energy feed and substitute for corn. Further analysis will help explain the differences and behaviors of corn, DDGS, MDGS, and WDGS regional price relationships over time.

Figure 6

Weekly prices of corn and dry, modified, and wet distillers' grains (dry matter basis): Nebraska ethanol plant, November 9, 2007-September 3, 2010
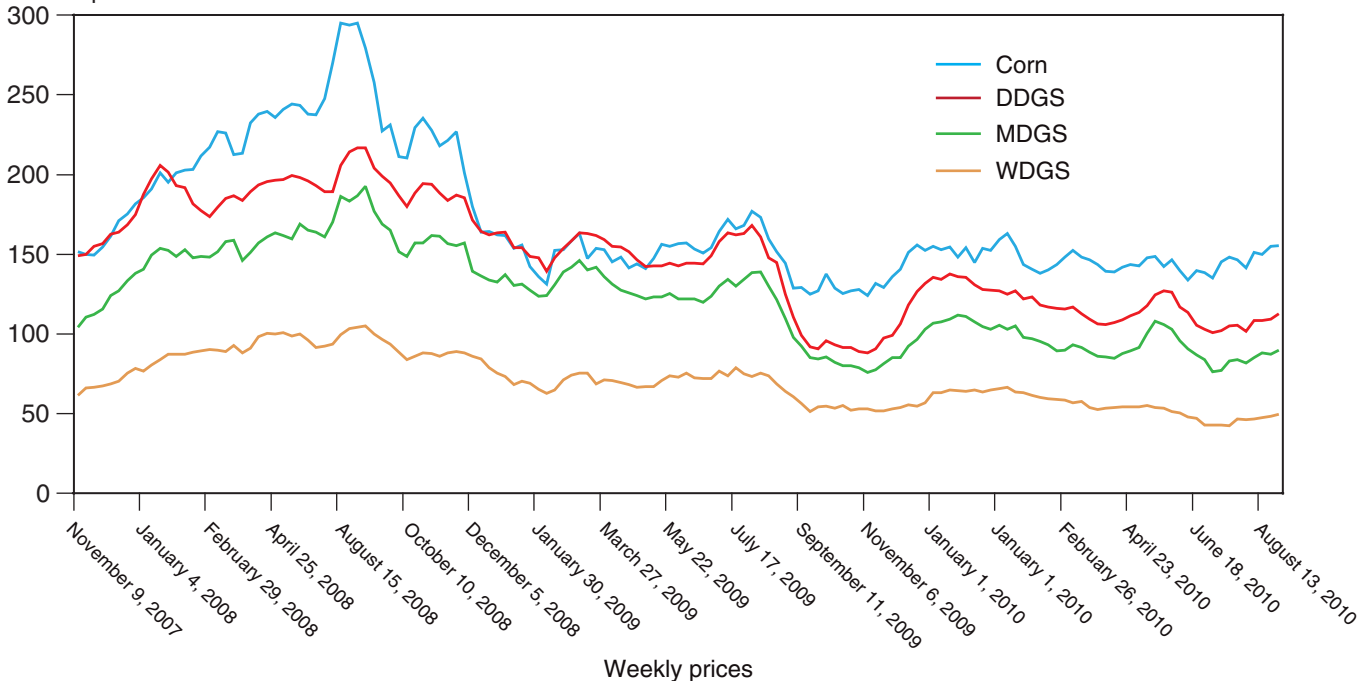
Note: Weekly prices for September-August marketing year.
Source: USDA, Agricultural Marketing Service, *Bioenergy Market News* reports.

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Summary and Conclusions

The authors of this report present a methodology for estimating supply and consumption for the U.S. distillers' grain market, providing a transparency that contributes to the quality of the data, which can then be used to compare the supply, use, and price relationships of DDGS with other feed sources (see "Appendix: Estimation of U.S. Distillers' Grains Supply and Use"). Using these estimates, we show the size and composition of the distillers' grain market in broad terms. These estimates can then be used to develop a broader understanding of the DDGS and larger feed markets.

As new markets develop, buyers and sellers struggle to determine how best to position the product in the market and at what price. Our method of estimating DDGS supply and use was presented to develop estimates consistent with similar estimates for corn and soybean meal. Estimated supply of U.S. distillers' grains is expected to total 33.3 mmt for 2009/10, more than double that for 2006/07. Most of this additional supply comes from corn dry-mill fuel ethanol production, with a lesser amount coming from dry-mill beverage ethanol distilleries. Imports account for a minor segment of the market. Growth in both ethanol and distillers' grains are expected to moderate in the future. Changing dry-mill ethanol technology may alter the future composition of distillers' grains and the application of DDGS in livestock feed.

Domestic U.S. feed and residual use comprises three-fourths of U.S. distillers' grain disappearance. Domestic feeders have rapidly adopted this product to take advantage of its nutrient and cost advantages because it provides good value per unit of energy and protein. This adoption occurred early despite many issues of product quality, consistency, handling, and feed safety, due to education and common industry practices. Foreign feeders are also beginning to discover the economic feed value of distillers' grains, and the rate of export growth has surpassed that found in the domestic feed market. Exports represented about a fourth of U.S. distillers' grain disappearance in 2009/10.

The authors used the findings in this report to address questions about the potential size of the DDGS supply relative to its potential feed use. The potential for current DDGS consumption in the United States generally exceeds future U.S. supply estimates. Future supply of DDGS was estimated at 38.6 mmt for 2019/20 compared with an estimated current potential U.S. DDGS feed consumption of 35.2 to 55.3 mmt. Additionally, expected distillers' grain export potential is estimated to range from 20 to 52 mmt, which would cover any feed use not covered by U.S. needs.

Corn and soybean meal prices are important determinants of DDGS prices and may explain why some producers rely on corn and soybean meal futures prices to establish DDGS prices, or why some producers use corn and soybean meal futures as a risk management tool. Another DDGS price discovery and risk management tool has become available with the initiation of a futures contract on April 26, 2010 for distillers' grain at the CME Group. Average prices of DDGS for most the past 4 marketing years (2006/07-2009/10) are now running at a discount to corn compared with an average

premium prior to the surge (May 1995 through August 2006) in distillers' grain production. As DDGS increasingly became an energy feed, soybean meal prices lost some of their connection to DDGS prices. Perhaps the increased seasonality of DDGS prices could contribute to the explanation of this trend. Corn, DDGS, MDGS, and WDGS regional price relationships need further analysis to better explain their differences and behaviors over time.

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Appendix:

Estimation of U.S. Distillers' Grain Supply and Use: A Transparent Methodology to Estimate U.S. Distillers' Grain Production and Consumption

The need for a transparent method to estimate the supply (production and imports) and disappearance (domestic feed consumption and exports) of distillers' grains is apparent because of the number of undocumented estimates of production and consumption that have been made and discrepancies and inconsistencies among these estimates (Voegele, 2009; Food and Agricultural Policy Research Institute (FAPRI), 2009; RFA, 2008; The ProExporter Network, 2007). Our methodology is similar to the process used by USDA's Economic Research Service to estimate supply and use for the major livestock feed sources, which distillers' grains have rapidly become. A consistent methodology allows analysts to research issues with distillers' grains, such as supply and disappearance (domestic and export). Our estimation method relies on published data, but inventories are not included in our estimate of supply, since there are no published data for inventories of distillers' grains.

Production estimates for DDGS have become available, but these estimation methods are less than transparent and difficult to apply generally (Wisner, 2008; FAPRI; Deutscher, 2009; RFA, September 2008; U.S. Department of Commerce, Census Bureau (a)).[1] U.S. Census Bureau statistics are viewed by Government and industry analysts as incomplete and under-report DDGS production based on other reports of ethanol production. For example some DDGS production estimates are expressed on a calendar year basis, while other estimates are for a crop marketing year; assumptions about conversion factors and product breakouts also likely vary. For example, Wisner (2008) estimated production and exports of distillers' grain in 2007/08 at 25.7 and 3.9 million short tons, respectively. FAPRI estimated production and exports of DDGS in 2007/08 at 22.8 and 2.4 million short tons, respectively. RFA reported that 14.6 mmt of DDGS were produced in calendar year 2007 (RFA, 2008). In a later document, RFA reports estimated production of distillers' grains at 19.3 million metric tons for corn marketing year 2007/08 (RFA, September 2008).

Differences in estimates can occur due to assumptions on yield of distillers' grains per bushel of corn turned into ethanol. Estimates range from 16.75 to 18 pounds per bushel of corn fermented for ethanol. Some analysts assume that all corn used for ethanol production is credited to the dry-mill process. Dry mills account for an increasing share of total ethanol production, but this process is not used across all ethanol production.

In May 2007, the Census Bureau began publishing information that provided the quantity of corn grind used to produce ethanol along with its feed coproducts of corn gluten meal, corn gluten feed, wet corn gluten feed, and corn germ meal (U.S. Department of Commerce, Census Bureau (a)). The corn and other grain grind from the dry mills, including beverage distillation, were provided along with the feed coproducts—distillers' wet grain, distillers' dried grain with solubles, distillers' dried grains, distillers' dried soluble, and

[1] The U.S. Census Bureau began publishing production estimates of distillers' grains in May 2007, but this estimating procedure does not yet appear to capture all production based on other less direct methods, including the methodology examined in this report. The Renewable Fuels Association released a study in September 2008 that contained a production estimate of DDGS, corn gluten feed, and corn gluten meal for 2007.

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condensed distillers' solubles. A transparent methodology to estimate the production of distillers' grains allows for cross checking with the production estimates provided by the Census Bureau as well as with other industry or university production estimates. Census Bureau production estimates do not specify the moisture content of their listed coproducts. For example, university and USDA/AMS report moisture content of distillers' dry grains with solubles at 10 to 12 percent, modified wet distillers grains with solubles at 50 to 55 percent moisture, and wet distillers' grains with solubles at 65 to 70 percent moisture. Thus, it is difficult to determine whether U.S. Census Bureau's production estimates are similar to production estimates from other sources. Furthermore, our methodology can estimate data prior to the start of the Census Bureau statistics in May 2007.

Currently, the Census Bureau provides estimates for U.S. soybean meal grind and U.S. wheat flour grind that are used by both the Government and the industry. With time, the Census Bureau estimates of feedstocks used for both wet- and dry-mill ethanol plants and their resulting ethanol feed coproducts should become more reliable and useful to the distillers' grain market to gauge supply and consumption.

Meanwhile, we present a methodology that produces a transparent source of information on feedstocks for both wet- and dry-mill ethanol plants and their resulting feed coproducts that will be useful for the distillers' grain market to gauge supply and consumption. We followed USDA's methodology to estimate supply and demand for commodities:

- For production, we estimated the amount of corn used by beverage distilleries and the resulting amount of distillers' grains produced from this production process.

- Next, we estimated the amount of corn used by dry-mill ethanol plants and the resulting distillers' grains.

- Then we added imports of distillers' grains derived from U.S. Department of Commerce trade data and from the Economic Research Service's Feed Grains Database (USDA, ERS).

- By adding these components, we estimated supply of distillers' grains.

- From this supply, we subtracted exports derived from U.S. Department of Commerce trade data and from the ERS Feed Grains Database to arrive at feed and residual use.

Please note that the split for ethanol production between wet- and dry-mill corn ethanol plants is an estimate. Not all relevant data were available to make these estimates, but the estimation steps follow. For example, the corn oil yield per crop year should vary by crop year following actual oil yield variation by crop year. Since these data were unavailable, a constant estimate of 1.64 pounds per bushel processed was used. Furthermore, the amount of corn oil produced by dry mills later becomes an issue once fractionation began at some of the dry-mill plants. The Census Bureau report (U.S. Department of Commerce, Census Bureau (a)) may not be picking up this increase in oil from dry mills, so an assumption was made to account for this situation. Should actual data for estimates of fuel ethanol produced by wet mills become available, these data should be used instead of our estimates.

Estimated Supply

Production

Distillers' grains are produced from two sources—dry-mill beverage distilleries and dry-mill fuel ethanol producers. An estimation procedure for the amount of distillers' grains produced is explained below.

Dry-mill beverage distilleries—Our goal was to estimate the amount of corn used by dry-mill beverage distilleries and the amount of distillers' grains produced from this production process. The quantity of distillers' grains produced is shown in table 1, column 1. The amount of corn used was based on U.S. Department of the Treasury, Alcohol and Tobacco Tax and Trade Bureau data. Bushels of corn used for distilled spirits were multiplied by 17.5 pounds to arrive at the amount of distillers' grains produced per bushel of corn used. As observed from table 1, this production figure has remained rather stable in the past few years at 0.9 mmt, but the share of total corn used for ethanol production has declined.

Dry-mill fuel ethanol—We needed to estimate the amount of corn used by dry-mill fuel ethanol plants. Since we know the total amount of corn used for fuel ethanol from the monthly World Agricultural Supply and Demand Estimates (WASDE), we had to determine the amount of corn used by wet-mills and subtract it from the total to arrive at the amount of corn used by dry-mills for fuel ethanol production. The reason for this separation is that different coproducts result from each production method.

Estimation methodology—The quantity of corn oil produced by wet corn mills must first be converted into the quantity of corn processed by wet mills. Corn oil is a coproduct created by wet mills, regardless of the other products produced, such as high-fructose corn syrup (HFCS), glucose/dextrose, starch, or ethanol. As seen in estimation step 1 (table 2, column 1), the total amount of corn processed by corn wet mills can be computed from total corn oil production minus that produced from dry mills divided by the yield of oil per wet-mill bushel processed. Both corn oil numbers produced at wet and dry mills were taken from the U.S. Department of Commerce (a), Census Bureau data. In the past 3 years, the corn oil amount produced by dry mills was increased to account for oil produced from fractionation (front-end), increasing this estimate from 1.9 percent for marketing year 2006/07, to 2.0 percent for marketing year 2007/08, and to 2.25 percent for marketing years 2008/09, 2009/10, and 2010/11.[2]

Next, the amount of corn used for fuel ethanol production by wet mills must be determined. Since we estimated total corn used by the wet-mill plants, we subtracted the amount of corn used for HFCS, glucose/dextrose, and starch to arrive at the corn available for ethanol production as shown in estimation step 2 (table 2, columns 3-8).

The bushels of corn used by wet mills for fuel ethanol produced from the total corn used by both wet and dry mills for fuel ethanol production must then be subtracted. Total corn used by both wet and dry corn mills for fuel ethanol production can be obtained from USDA's *WASDE*. The difference is the amount of corn used by dry mills for fuel ethanol production (see table 3). This calculation is illustrated in estimation step 3.

[2] Future adjustments must be based on whether corn oil continues to be removed from the fractionation (front-end) process.

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Estimation steps

1. Total corn oil produced for 2009/10 was estimated at 2.50 billion pounds (table 2, column 1) minus 2.5 percent of the total estimated to be produced by dry mills equaled 2.44 billion pounds of corn oil produced by wet mills (table 2, column 2) divided by 1.64 pounds of corn oil per wet mill bushel processed equaled 1,490.1 million bushels of corn processed by corn wet mills (table 2, column 3).

2. Total bushels of corn estimated to have been processed by wet-mill corn plants in 2009/10 equaled 1,490.1 million bushels (table 2, column 3) minus corn used to produce HFCS equal to 515.0 million bushels (table 2, column 4) plus glucose/dextrose equaled 255.0 million bushels (table 2, column 5) plus starch equaled 245.0 million bushels (table 2, column 6) equaled 475.1 million bushels of corn used by wet-mill plants to produce fuel ethanol (table 2, column 8).

3. Total corn estimated to be used for fuel ethanol production in 2009/10 equaled 4,535.0 million bushels (table 3, column 1) minus corn used by wet mills for fuel ethanol production which equaled 475.1 million bushels (table 3, column 2) equaled 4,059.9 million bushels of corn used by dry mills for fuel ethanol production (table 3, column 3).

4. 4,059.9 million bushels of corn used by dry mills for ethanol production (table 3, column 3) multiplied by 17.4 pounds of DDGS per bushel of corn processed by dry-mill ethanol plants equaled 32.0 mmt produced (pounds divided by 2204.622 pounds per metric ton) (table 1, column 2).

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[1] A corn oil yield of 1.64 pounds per bushel is used for these calculations. This yield was computed as follows: 15.5 percent moisture content per bushel, test weight of 56 pounds per bushel and a fat content per bushel of 4.3 percent of dry matter (.043 x 47.32 lbs/bu. = 2.035 lbs. /bu.). Next, we assume that 85 percent of the oil is located in the germ and an extraction rate of 95 percent, yielding (2.035 lbs/bu. x .85x .95 = 1.64 pounds/bu.) (Corn Refiners Association, p. 5, 2006).

The final step, as seen in estimation step 4, is to multiply the amount of corn used by dry mills to produce ethanol by 17.5 pounds—the weight of distillers' grains after the fermentation process (table 1, column 2). Common estimates for this weight range from 16.75 pounds to 18 pounds of DDGS per bushel of corn fermented for ethanol production. We used 17.5 pounds for the earlier years and 17.4 pounds for the later years 2007/08 through 2010/11 because of fractionation, both front-end and back-end, and the removal of corn oil during the production of fuel ethanol by the dry mills.[3]

Since 2002/03, most U.S. ethanol was produced from dry-mill corn ethanol plants. The share of corn use by dry mills continues to rise, ranging from about 54 percent in 2002/03 to 90 percent in 2009/10 (see table 3).

Imports
Data on imports of distillers' grains were obtained from the U.S. Department of Commerce (b) and the Economic Research Service's Feed Grains Database. Unfortunately, distillers' grains are part of a category called "brewers and distillers dregs and wastes." Brewer's grains are found in this category, but so too are noncorn distillers' grains. Currently, most of these imports originate from Canada and could include noncorn feedstocks, such as barley or wheat. Regardless of the unknown products in this category, adjustments seem unwarranted since the quantity is small, ranging from 0.1 to 0.5 mmt (table 1, column 3).

[3] The reduction of distillers' grain yield per bushel of corn processed for dry-mill ethanol production from 17.5 to 17.4 is an attempt to capture the effects of fractionation and removal of oil from ethanol production process by dry-mill plants. Additional analysis will be required to derive a more precise estimate of these effects.

Estimated Use

Domestic Feed and Residual Use
Residual use was computed by subtracting exports from supply (table 1, column 4). The quantity of U.S. distillers' grain supply for domestic use in 2009/10 was estimated at 25.0 mmt (table 1, column 1). Domestic feed and residual use accounted for 75 percent of use, but this share is declining.

Exports—Data on exports of distillers' grains were obtained from the USDA Feed Grains Database. Despite the title of this export category—brewers' and distillers' dregs and wastes—most of the product in this category comes from distillers' grains. For example, U.S. production of brewers' grains for 1988/89 was 117,900 short tons, the last year of published data (Ash, 1992). If one were to assume that 18 percent of this production was still being exported, the portion of production exported in 1988/89, we would expect that 117,900 short tons x 18 percent = 21,222 short tons or 21,222 short tons x 0.9071 = 19,252 metric tons would be exported. Regardless of the unknown product in this category, adjustments seem unwarranted since the quantity is small. Exports of 19.3 metric tons of brewers' grains would be considered high since corn consumption for beer production has declined since 1988/89. Exports of distillers' grains have accelerated since 2003/04, from less than 1.0 mmt to an estimated 8.3 mmt for 2009/10 (table 1, column 5).[4] Accelerating exports are expected to reach 25 percent of total disappearance in 2009/10, despite increasing U.S. feed and residual use of distillers' grains.

[4] Similar calculations were made by Dooley in December 2008, but were based on RFA calendar year production numbers and calendar year exports.