Update of Distillers Grains Displacement Ratios for Corn Ethanol Life-Cycle Analysis

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1 Introduction

Production of corn-based ethanol (either by wet milling or by dry milling) yields the following coproducts: distillers grains with solubles (DGS), corn gluten meal (CGM), corn gluten feed (CGF), and corn oil. Of these coproducts, all except corn oil can replace conventional animal feeds, such as corn, soybean meal, and urea.

Displacement ratios of corn-ethanol coproducts including DGS, CGM, and CGF were last updated in 1998 at a workshop at Argonne National Laboratory on the basis of input from a group of experts on animal feeds, including Prof. Klopfenstein (University of Nebraska, Lincoln), Prof. Berger (University of Illinois, Urbana-Champaign), Mr. Madson (Rapheal Katzen International Associates, Inc.), and Prof. Trenkle (Iowa State University) (Wang 1999). Table 1 presents current dry milling coproduct displacement ratios being used in the GREET model.

TABLE 1 Coproduct Displacement Ratios (lb of displaced product per lb of coproduct)[a]

Coproduct	Ratio
DGS	
Corn	1.077
Soybean meal	0.823

[a] Source: Wang 1999

The current effort focuses on updating displacement ratios of dry milling corn-ethanol coproducts used in the animal feed industry. Because of the increased availability and use of these coproducts as animal feeds, more information is available on how these coproducts replace conventional animal feeds. To glean this information, it is also important to understand how industry selects feed.

Because of the wide variety of available feeds, animal nutritionists use commercial software (such as Brill Formulation™) for feed formulation. The software recommends feed for the animal on the basis of the nutritional characteristics, availability, and price of various animal feeds, as well as on the nutritional requirements of the animal (Corn Refiners Association 2006). Therefore, feed formulation considers both the economic and the nutritional characteristics of feed products.

2 Coproducts from Corn Ethanol Dry Milling Plants

Distillers grains are the only coproduct from the corn ethanol dry milling process. Current U.S. industrial average DDGS yield is 5.4 bone-dry lb/undenatured gal EtOH. Generally, distillers grains are combined with condensed distillers solubles to form DGS, which are sold either as dry DGS (DDGS) or wet DGS (WDGS). A comparison of chemical composition of corn (NRC 1998) and DDGS (University of Minnesota 2008) is presented in Table 2.

TABLE 2 Major Components of Corn and DDGS (dry matter basis)

Item	Corn grain[a]	DDGS[b]
Dry matter (%)	85.5	89.3
Crude protein (%)	8.3	30.8
Fat (%)	3.9	11.1

[a] Source: NRC 1998 and White & Johnson 2003

[b] Source: University of Minnesota 2008

2.1 Update of Displacement Ratios of Distillers Grains

The methodology to update displacement ratios for DGS consists of the following four steps:

1. Characterize U.S. DGS production, recommended feed composition, and animal performance, with inclusion of distillers grains;

2. Characterize U.S. distillers grains consumption by animal type;

3. Characterize life cycle of various animals, to compare animal performance with or without distillers grains; and

4. Calculate the displacement ratio of distillers grains by using these data.

2.1.1 Step 1: Characterize U.S. DGS Production, Feed Composition, and Animal Performance

The Renewable Fuels Association (RFA) and the U.S. Grains Council regularly track annual U.S. distillers grains production, consumption, and exports, and the current displacement ratio update relies on this information. Feed composition for conventional animal feeds and distillers grains-based diets was determined on the basis of (1) information gathered from the literature review of the recent animal feeding studies and (2) follow-up discussions with experts in animal science. A recent National Agricultural Statistics Service-U.S. Department of Agriculture (NASS-USDA) survey (discussed in Step 2) has reported distillers grains use by animal type, and, on the basis of this survey, only beef, dairy, and swine diets are characterized for this update.

2.1.1.1 Annual U.S. DGS Production, Consumption, and Exports

Distillers grains production

As reported on the Renewable Fuels Association (RFA) website (RFA 2008), a typical dry mill ethanol plant can produce as much as 2.8 gallons of denatured ethanol (2.72 gallons of un-denatured ethanol[1]) and more than 16 pounds of distillers grains from a bushel of corn. The RFA website also reports historic distillers grains production, and this information is listed in Table 3.

TABLE 3 Annual U.S. Distillers Grains Production[a]

Year	DGS Production (million metric tons)[b]	DGS Production (million bushels of corn equivalent)[c]	DGS Production (protein equivalent-million bushels of corn)[d]
1999	2.3	91	336
2000	2.7	106	394
2001	3.1	122	453
2002	3.6	142	526
2003	5.8	228	847
2004	7.3	287	1,066
2005	9.0	354	1,315
2006	12.0	472	1,753
2007	14.6	575	2,133

[a] Source: RFA 2008

[b] As received basis, i.e. dry matter content of 89.3%

[c] 1 bushel of corn = 56 lb

[d] Assuming average protein content for DGS and corn to be 30.8 and 8.3%

U.S. distillers grains consumption

Distillers grains consumption data, especially by animal type, are important for calculating displacement ratio of distillers grains as animal feed, because distillers grains replace varying amounts of conventional feed for different animals, as discussed above.

CHS, Inc., one of the major marketers of distillers grains in the United States, provided the following information (Broderick 2008) regarding distillers grains consumption (Table 4). The RFA website (RFA 2008) also reports this information, but the animal distribution is slightly different from that obtained directly through CHS.

[1] Assuming addition of 4.7% denaturant by volume

TABLE 4 U.S. Distillers Grains Consumption by Animal Type

Animal Type	CHS	CHS/RFA	CHS/RFA (excluding Poultry)
Dairy	44%	42%	44.2%
Beef	42%	42%	44.2%
Swine	9%	11%	11.6%
Poultry	5%	5%	

Additionally, the RFA website (RFA 2008) also reports that 64% of the distillers grains are consumed as DDGS, and the remaining 36% in the wet form as WDGS.

For the current displacement ratio update, consumption data reported by the RFA were used, while poultry consumption was excluded because feed composition and performance data available for poultry were insufficient.

U.S. distillers grains exports

U.S. DGS exports roughly account for 15% of the annual U.S. production. The market for DGS has diversified from the European Union as the main market to Mexico, Southeast Asia, Canada, and Taiwan as significant customers, as shown in Table 5. All of the DGS exports are consumed in the animal feeding industry, and for the current displacement ratio update, it was assumed that all export markets have an animal distribution similar to that of the United States (Table 4).

TABLE 5 U.S. DGS Exports (1,000 metric tons)[a]

Country/Region	2005/2006[b]	2006/2007[b]
Mexico	281	608
European Union	481	204
Southeast Asia	168	262
Canada	114	189
Taiwan	73	126
Other	114	390
Total	1,229	1,779

[a] Source: U.S. Grains Council 2007 Annual Report

[b] Sept. – Aug., marketing year

2.1.1.2 DGS Inclusion in Feed and Animal Performance

Beef cattle

A 2008 review (Klopfenstein et al. 2008a) of the use of distillers by-products as beef cattle feed conducts a meta-analysis of nine experiments for wet distillers grains plus solubles (WDGS) and five experiments for dry distillers grains plus solubles (DDGS). This meta-analysis, based on the optimal Gain:Feed[2] (G:F) value, recommends a 30–40% inclusion rate for WDGS and a 20% inclusion rate for DDGS. On the basis of this publication and additional information about feed composition received from Prof. Klopfenstein (2008b), feed composition and animal performance at various inclusion rates for DDGS and WDGS are presented in Table 6 and Table 7. As per Prof. Klopfenstein, urea is removed from the supplement portion of feed, when more than 15% distillers grains are included in the diet.

The animal performance data presented in Table 6 and Table 7 clearly show significantly higher average daily gain[3] (ADG, kg/d) when distillers grains are fed, in comparison with the control diet.

TABLE 6 Feed Composition and Animal Performance for Beef Cattle with DDGS Inclusion[a]

	DDGS inclusion Rate (%)				
	Control	10	20	30	40
Parameter	(% of Dry Matter)				
Corn	87.5	77.5	67.5	57.5	47.5
Hay	7.5	7.5	7.5	7.5	7.5
Supplement[b]	5	5	5	5	5
Urea[c]	1.3	0.5	0	0	0
DDGS	0	10	20	30	40
DMI (kg/d)	10.17	10.40	10.53	10.56	10.49
ADG (kg/d)	1.56	1.65	1.69	1.70	1.66
G:F	0.152	0.160	0.159	0.155	0.152

[a] Sources: Klopfenstein et al. 2008a, Klopfenstein 2008b

[b] Contains vitamins, minerals, and feed additives.

[c] Included in the supplement, replacing the carrier (such as corn).

[2] G:F is a ratio of ADG to dry matter intake (DMI). It evaluates the effectiveness of diet on animal performance.

[3] Average daily gain (ADG) is a performance parameter that measures weight gain per day by animal.

TABLE 7 Feed Composition and Animal Performance for Beef Cattle with WDGS Inclusion[a]

	WDGS inclusion Rate (%)					
	Control	10	20	30	40	50
Parameter	----------------------------------(% of Dry Matter) --------------------------------					
Corn	87.5	77.5	67.5	57.5	47.5	37.5
Hay	7.5	7.5	7.5	7.5	7.5	7.5
Supplement[b]	5	5	5	5	5	5
Urea[c]	1.3	0.5	0	0	0	0
WDGS	0	10	20	30	40	50
DMI (kg/d)	10.12	10.31	10.33	10.20	9.90	9.44
ADG (kg/d)	1.57	1.68	1.74	1.76	1.73	1.66
G:F	0.155	0.162	0.168	0.172	0.174	0.175

[a] Sources: Klopfenstein et al. 2008a, Klopfenstein 2008b

[b] Contains vitamins, minerals, and feed additives.

[c] Included in the supplement, replacing the carrier (such as corn).

Dairy cattle:

A 2006 publication by Anderson et al. (2006) evaluates the effects of feeding dried or wet distillers grains with solubles on the lactation performance of dairy cows. This study considers DDGS/WDGS inclusion rates of 10% and 20% of diet dry matter and compares the milk production and composition for these diets with the control diet (corn + soybean meal). The ingredient content of these diets is described in Table 8. From this table, the amount of corn and soybean meal being displaced at 10% and 20% inclusion of distillers grains can be calculated.

The comparison of milk production and composition presents significantly higher milk yields for distillers grains with solubles (DGS) -fed cows vs. the control (CON) diet, whereas the percentage of fat percentage is significantly higher for WDGS than that for DDGS and CON. The protein percentages are similar for CON and DGS diets. Both the milk fat yield and protein yield are significantly higher for DGS-based diets than the CON diet. This comparison is summarized in Table 9.

TABLE 8 Ingredient Content of Feed for Dairy Cattle[a]

Item	Control	10% DDGS	20% DDGS	10% WDGS	20% WDGS
	----------	----------	(% of DM)	----------	----------
Corn silage	25	25	25	25	25
Alfalfa hay	25	25	25	25	25
Corn, ground	35.6	31.3	26.7	31.3	26.7
Soybean meal, 44% CP	12.5	7	1.6	7	1.6
DDGS	0	10	20	0	0
WDGS	0	0	0	10	20
Salt	0.53	0.53	0.53	0.53	0.53
Magnesium oxide	0.05	0.05	0.05	0.05	0.05
Limestone	0.82	0.82	0.82	0.82	0.82
Dicalcium phosphate	0.22	0	0	0	0
Dairy Micro premix[b]	0.25	0.25	0.25	0.25	0.25
Vitamin E premix	0.07	0.07	0.07	0.07	0.07

[a] Source: Anderson et al. 2006

[b] 10% Mg; 2.6% Zn; 1.7 ppm Mn; 4,640 ppm Fe; 4,712 ppm Cu; 396 ppm I; 119 ppm Co; 140 ppm Se; 2,640,000 IU/kg vitamin A; 528,000 IU/kg vitamin D3; and 10,560 IU/kg vitamin E

Table 9 Milk Yield and Composition for Cows Fed Control Diet and Diets Containing 10% DDGS, 20% DDGS, 10% WDGS, and 20% WDGS[a]

	Diet				
Item	Control	10% DDGS	20% DDGS	10% WDGS	20% WDGS
DMI (kg/d)	23.4	22.8	22.5	23	21.9
Milk (kg/d)	39.8	40.9	42.5	42.5	43.5
Fat (%)	3.23	3.16	3.28	3.55	3.4
Fat (kg/d)	1.28	1.32	1.39	1.44	1.43
Protein (%)	3.05	3.01	3.02	3.11	3.06
Protein (kg/d)	1.2	1.22	1.29	1.29	1.33
ECM[b] (kg/d)	38.4	39.6	41.3	41.7	42
Feed efficiency[c]	1.7	1.79	1.87	1.84	1.92

[a] Source: Anderson et al. 2006

[b] ECM = Energy corrected milk

[c] Feed efficiency = (ECM/DMI)

Swine

Feed composition for swine was based on feedback received from Prof. Shurson (2008), who recommended DDGS inclusion at 10% in grower swine feed (and, as a "rule of thumb," in a 1,000-kg batch of grower swine feed). He also recommended that 100 kg of DDGS and 1.5 kg of limestone replace 89 kg of corn, 9.5 kg of soybean meal (46% CP), and 3 kg of dicalcium phosphate ($CaHPO_4$).

The information about feed composition from Prof. Shurson agrees with the feeding recommendations (Shurson and Spiehs 2002) published on the University of Minnesota DDGS website (www.ddgs.umn.edu), but it differs from the feed composition used by Whitney et al. (2006) in their study. The experimental swine grower feed used by Whitney et al. contains soybean oil in addition to DDGS, corn, and soybean meal. The difference in feed composition can be attributed to the lower quality of DDGS used in this study — the experimental feed had a crude protein (CP) content of 23.9%, as compared to the average protein content of 30% for the current commercially available DDGS.

Data on animal growth reported by Whitney et al. present similar G:F and ADG values for the control and 10% DDGS diets, which indicates equivalent performance for a 10% DDGS diet compared to a control diet. A recent follow-up study by Spencer (2008) also reported similar G:F and ADG values for a corn-soybean meal control diet and a 15% DDGS diet. The growth performance data from both studies are summarized in Table 10.

TABLE 10 Growth Performance for Swine with DDGS Inclusion

	Whitney et al. 2006[a]		Spencer 2008			
Parameter	**Control diet**	**10% DDGS inclusion**	**Control diet**	**15% DDGS inclusion**	**30% DDGS inclusion**	**P value (DDGS vs. control)**
ADG (kg/d)	0.862	0.859	0.912	0.921	0.907	0.67
G:F	0.36	0.36	0.40	0.40	0.39	0.16

[a] P value was determined for 10%, 20%, and 30% DDGS inclusion rates vs. control. However, growth performance at the 10% inclusion rate was statistically insignificant compared to control.

2.1.2 Step 2: Characterize U.S. Distillers Grains Consumption by Animal Type

A 2007 NASS-USDA ethanol coproducts survey has been used to select distillers grains inclusion rate (by animal type) for this update. Results from this survey are summarized below.

The NASS-USDA survey (NASS-USDA 2007) was conducted in 2007 by the Nebraska Corn Development, Utilization & Marketing Board. The board contacted 9,400 livestock operations in Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin regarding use of ethanol co-products in their animal feeding operations. The survey gathered information on dairy cattle, cattle on feed, beef cattle (cow/calf), and hogs.

This survey addressed the use of ethanol co-products from dry milling, as well as wet milling. For dry milling co-products, the survey reported use of DDGS, as well as condensed distillers solubles (CDS), distillers dried grains no solubles (DDG), and distillers wet grains. However, use of wet distillers grains with solubles (WDGS) was not reported in this survey. DDGS data from this survey are presented in Table 11.

TABLE 11 Coproducts Fed by Animal Type[a] — Distillers Dried Grains with Solubles (DDGS)

Item	Operations Who Use This Type (%)	Average Peak Inventory[b] (Head)	Moisture Content in DDGS (wt%, dry basis)	Inclusion Rate (%)	Average Amount Fed per Animal per Year (kg)
Dairy Cattle	22	272	11	8	455
Cattle on feed[c]	14	1,590	15	23	416
Beef Cattle	13	344	12	22	180
Hogs	37	27,708	12	10	27

[a] Source: NASS – USDA 2007

[b] 2007 refers to average peak inventory of operations that fed particular coproduct during 2006.

[c] Cattle on feed refers to beef cattle in commercial feedlots.

The inclusion rates reported by the NASS-USDA survey approximately agree with the recommended DDGS inclusion rates specified in step 1 for beef cattle (20%) and swine (10%). For dairy cattle, this survey reports 8% DDGS inclusion; therefore, a scenario of 10% DDGS inclusion in Anderson et al. (2006) was selected for dairy cattle.

For WDGS, a recommended inclusion rate of 40% for beef cattle was selected, while a 10% inclusion rate for dairy cattle was selected.

2.1.3 Step 3: Characterize Life Cycle of Animals

The impact of feeding distillers grains on animal performance was discussed in step 1 of this update. For beef and dairy cattle, feeding distillers grains clearly leads to improved animal performance in terms of faster weight gain for beef cattle and increased milk production for dairy cattle. However, swine growth performance remains unchanged, with similar G:F and weight gain values (Whitney et al. 2006, Spencer 2008; see Table 10).

To quantify the difference in animal performance for beef and dairy cattle as a result of feeding distillers grains, the life cycle of beef and dairy cattle must be characterized. This characterization was based on feedback from experts in animal science.

2.1.3.1 Beef Cattle

On the basis of feedback from Prof. Berger (2008), feeding distillers grains begins at an average body weight of 227 kg (500 lb), when cattle are moved into feedlots, at which point the feed is switched from grass/hay to a higher-energy and protein-based diet. Feeding distillers grains continues until the cattle are slaughtered at an average body weight of 590 kg (1,300 lb). This information is summarized in Table 12.

TABLE 12 Life Cycle of Beef Cattle

Initial weight (kg)	227
Final weight (kg)	590
Weight gain (kg)	363

2.1.3.2 Dairy Cattle

Dairy cattle performance is measured in terms of milk production. An average dairy cow over a lifetime of 4–5 years has 2.8 lactation periods, with each lactation lasting 10 months (Schingoethe 2008, Blayney 2008). Note that these numbers are for commercial dairy operations, for which the focus is on increased daily milk production. For non-commercial operations, dairy cows have more lactation periods but lower daily milk production. This information is summarized in Table 13.

TABLE 13 Life Cycle of Dairy Cattle

Average lactation periods/cow	2.8
Lactation period (months)	10
Total lifecycle lactation time (days)	840

2.1.4 Step 4: Results — Displacement Ratio of Distillers Grains

After characterizing animal performance, U.S. distillers grains production and consumption, and life cycle of animals, the displacement ratio of distillers grains was calculated in the following steps:

a. Determine lifetime dry matter intake (DMI) for animals fed a conventional diet and a recommended distillers grains-based diet, aiming for equivalent animal performance (i.e., equal lifetime weight gain for beef cattle and equal lifetime milk production for dairy cattle);

b. Determine lifetime conventional feed displacement, which includes direct replacement due to distillers grains inclusion and feed savings due to improved animal performance;

c. Determine distillers grains displacement ratio for each animal type on the basis of lifetime distillers consumption, lifetime conventional feed displacement, and market share of DDGS and WDGS (RFA 2008); and

d. Calculate overall displacement ratio as a sum of displacement ratio by animal type weighted over the market fraction for each animal (as specified in Table 4).

The displacement ratio for each animal type calculated by following steps 4a–d are presented in Table 14.

Table 14 Distillers Grains Displacement Ratio by Animal Type

	Inclusion Rate, by Animal Type				
	Beef Cattle		Dairy Cattle		Swine[a]
Parameter	20% DDGS	40% WDGS	10% DDGS	10% WDGS	10% DDGS
Lifetime DDGS/WDGS consumption (kg)	452	831	1864	1809	–
Lifetime corn displacement (kg)	520	1060	1266	1491	–
Lifetime SBM[b] displacement (kg)	–	–	1152	1191	–
Lifetime urea displacement (kg)	30	30	–	–	–
Normalized corn displacement (kg/kg distillers grains)	1.151	1.276	0.679	0.824	–
Normalized SBM displacement (kg/kg distillers grains)	–	–	0.618	0.658	–
Normalized urea displacement (kg/kg distillers grains)	0.067	0.037	–	–	–
DDGS/WDGS market share (%)	64	36	64	36	100
Corn displacement (kg/kg distillers grains)	1.196		0.731		0.890
SBM displacement (kg/kg distillers grains)	–		0.633		0.095
Urea displacement (kg/kg distillers grains)	0.056		–		–

[a] Lifetime DDGS consumption for swine was not calculated because no difference in animal performance was found when fed distillers grains compared to control feed (see Table 10).

[b] SBM = Soybean meal

Final distillers grains displacement ratio results are presented below in Table 15. These results indicate that 1 kg of distiller grains displace 1.271 kg of conventional feed ingredients, thus signifying improved animal performance obtained by feeding distillers grains.

Table 15 Distillers Grains Displacement Ratio

Parameter	Beef	Dairy	Swine	Overall Ratio (kg/kg distillers grains)
Market share (%)	44.2	44.2	11.6	100
Corn	1.196	0.731	0.890	0.955
Soybean meal	–	0.633	0.095	0.291
Urea	0.056	–	–	0.025

2.1.5 Methane Emission Savings from Enteric Fermentation Reduction of Cattle Fed with DGS

Methane (CH_4) emissions due to enteric fermentation in animals are a significant source of greenhouse gas emissions, accounting for 28% of the total agriculture related greenhouse gas emissions in United States (EPA 2008). CH_4 emissions from beef and dairy cattle represent 71 percent and 24 percent of total CH_4 emissions from enteric fermentation, respectively. Since feeding distillers grains improves animal performance for beef and dairy cattle, these animals remain in commercial feedlots for a shorter period (over their entire lifecycle, see section 2.1.3) compared to animals on conventional diet. Therefore, CH_4 emissions over the lifecycle of animals fed with distillers grains are lower compared to those fed with conventional diets. University of Nebraska's BESS model has first quantified these savings over the entire life cycle of corn ethanol production (Liska et al. 2008).

For this study, greenhouse gas savings were calculated based on EPA emission factors for enteric fermentation. The calculated CH_4 savings as CO_2 equivalent are presented in Table 16. As the table shows, the reduction in CH_4 emissions from enteric fermentation of animals by DGS is about 3,381 grams of CO_2e per million Btu of ethanol produced, or 258 grams per gallon of ethanol produced.

Table 16 Greenhouse Gas Savings due to Reduced Enteric Fermentation

Animal Type	Market Share (%)	Emission Factor (kg CH_4/head/year)	CH_4 Savings as CO_2 Equivalent (g/million Btu EtOH)
Dairy	44.2	130.26	5,244
Beef	44.2	33.75	2,402
Swine[a]	11.6	1.5	0
Total	100	–	3,381

[a] No greenhouse gas savings for swine because animal performance remains same when being fed with distillers grains (Whitney et al. 2006, Spencer 2008; see Table 10).

2.1.6 Impact of 2007 Energy Independence and Security Act on DGS Displacement Ratio

The Energy Independence and Security Act (EISA) of 2007 mandates the production of 15 billion gallons of corn-based ethanol by 2015, which will result in the production of more than twice the amount of DGS produced in 2007. This comparison and underlying assumptions are presented in Table 17.

TABLE 17 DGS Market Growth

Year	U.S. Ethanol Production (billion gal per year)	DGS Production (bone-dry million metric tons)[a]
2007[b,c]	6.5	12.7
2015[d,e]	15	30.5

[a] DGS yield is 5.1 bone-dry lb/gal of denatured ethanol (Source: RFA 2008).

[b] 2007 ethanol production volume obtained from RFA website.

[c] 2007 share of dry mill EtOH is 84% (Source: Staff 2008).

[d] 2015 ethanol production volume estimated on the basis of the EISA 2007.

[e] 2015 share of dry mill EtOH is 87.5% (Source: GREET 1.8b, 2008).

The theoretical maximum U.S. market size for distillers grains has been estimated at 40.3 million metric tons by Cooper (2006), assuming maximum inclusion rates of 40% for dairy, 40% for beef, 20% for swine, and 10% for poultry at 100% market penetration. This estimate clearly suggests that U.S. DGS markets approach saturation at 15 billion gallons of corn ethanol production, while DGS exports are assumed to remain fixed at 15%.

TABLE 18 Distillers Grains Displacement Ratio (2015 Scenario)

Feed Type	Ratio (kg/kg distillers grains)
Corn	0.947
Soybean meal	0.303
Urea	0.025

In the current update, the impact of 15 billion gallons of corn ethanol on the DGS displacement ratio was estimated by assuming inclusion rates of 20% DDGS/40% WDGS for beef, 20% DDGS/20% WDGS for dairy, and 30% for swine. At these inclusion rates with 80% market penetration, maximum U.S. DGS consumption in 2015 was estimated at 23.4 million metric tons. The remaining 7 million metric tons of DGS are assumed to be exported, and the export markets are assumed to have animal distribution similar to that in the United States. The updated DGS displacement ratio results are presented in Table 18. These results do not differ significantly from the current results for displacement ratio.

2.1.7 Animal Production Effects of Addition of DGS to Animal Feed Market

In 1998, the USDA simulated corn ethanol production and associated DGS production (See Wang 1999). The USDA simulations concluded that supply of DGS from corn ethanol production would result in decreased prices of animal feeds in the U.S. animal feed market, which would induce additional new meat and milk production in the U.S. The USDA simulations indicated an increase of 15.1% in new meat and milk production. This implies that 84.9% of the total DGS production will displace conventional animal feeds. However, the recent trends have shown that supply of DGS to the animal feed market does not cause decrease in animal feed prices, thus not inducing additional meat and milk production. For this reason, we have revised the GREET model to assume that all, not 84.9%, DGS production would be for displacement of conventional animal feeds.

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