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Integrating Bio-Fuel Production with Wisconsin Dairy Feed Requirements

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Abstract. *Both the production of corn ethanol and soy biodiesel yield coproducts which can be used as dairy feed. The extent to which the Wisconsin dairy herd can consume these feeds has not yet been considered. This paper considers the use of dried distillers grains with solubles (DDGS) and soybean meal, coproducts of corn ethanol and soy biodiesel production, respectively, in dairy rations across the state, and how this consumption could influence Wisconsin's biofuel production. DDGS and soybean meal were maximized in model dairy rations according to dairy nutritionist recommendations, including a dietary protein content of 17% of dry matter intake. Maximizing the use of DDGS for the entire Wisconsin dairy herd would require the production of an amount of ethanol with an energy content equivalent to about 15% of the energy currently consumed as gasoline in the state. Soy biodiesel production based on maximum soybean meal allowable in dairy diets would yield an amount of biodiesel which could replace about 6% of the energy used as petroleum diesel in Wisconsin. While the use of biofuels coproduced with DDGS and soybean meal can contribute an energy credit the energy balance of producing dairy rations, the economic cost of maximizing DDGS and soybean meal in dairy rations, based on historical feed prices, is greater than cost of typical rations currently fed in the state.*

Keywords. Biodiesel, biofuel, dairy feed, dairy nutrition, distillers grains, ethanol, soybean meal.

Introduction

The major dairy feed crops grown in Wisconsin are corn (for grain and for silage), soybeans, and alfalfa. These feed crops allow, in part, for the production of a statewide average of about 22 kg per day (49 lb/day) of milk by the state's 1.2 million dairy cows (WASS, 2004). Both soybean and corn crops have been considered as bioresources for fuel production. Dedicating all of the corn grown for grain in the state to ethanol production (which could produce at least 25% of the energy consumed as gasoline in Wisconsin) and all of the soybeans currently grown in the state to biodiesel production (which could replace at least 7% of the diesel fuel energy consumed in the state) would yield a biofuel supply equal to about 19% of the total annual energy currently consumed as petroleum diesel and gasoline in the state. The production of ethanol from corn yields a feed byproduct, dried distillers grains with solubles (DDGS). Soy oil, which can be used for biodiesel production, is produced as soybeans are crushed to yield soybean meal. This paper presents various scenarios of rationing dairy feed in order to maximize the use of soybean meal and DDGS. The feed scenerios considered were analyzed in terms of energy inputs and outputs, and the economic costs of the rations were also considered.

Impacts of Maximizing DDGS in Wisconsin Dairy Rations on Ethanol Production

The amount to which DDGS can be maximized in dairy rations varies according to nutritionist recommendations. Nutritional aspects of corn distillers grains in the dairy ration were analyzed by D.J. Schingoethe et. al. (2002) of South Dakota State University. This paper recommends feeding a maximum of 20% of the daily dry matter intake (DMI) per cow as distillers grains. The recommended forage when using 20% DDGS DMI for dairy is a 50:50 blend of corn silage and alfalfa. Daily DMI of 20% DDGS in dairy rations would require about 4.0 kg/day (9.0 lbs/day) of DDGS. Some dairy nutritionists recommend a maximum of 10% DDGS DMI per day due to DDGS's polyunsaturated fatty acid content (PUFA) concentration (Long View Animal Nutrition Center, 2005). Estimated 10% DDGS DMI per day for a typical Wisconsin dairy cow would be about 1.9 kg/day (4.3 lbs/day). Approximately 1.79 billion kg (3.94 billion lbs) DDGS would be needed to feed all the cows in the state 20% DDGS DMI annually. Utilizing DDGS for 10% of the state's annual dairy ration would use 850 million kg (1.9 billion lbs) of DDGS. Mass flow figures 1 and 2 are shown to illustrate annual DMI of 10% and 20% DDGS for the Wisconsin dairy herd.

Producing ethanol on the basis of maximizing DDGS content in Wisconsin dairy rations to 20% daily DMI per cow would require the production of about 2.22 billion liters (586 million gallons) of ethanol annually. Utilizing DDGS as 10% daily DMI for Wisconsin's dairy herd would require the production of 1.07 billion liters (282 million gallons) of ethanol each year.

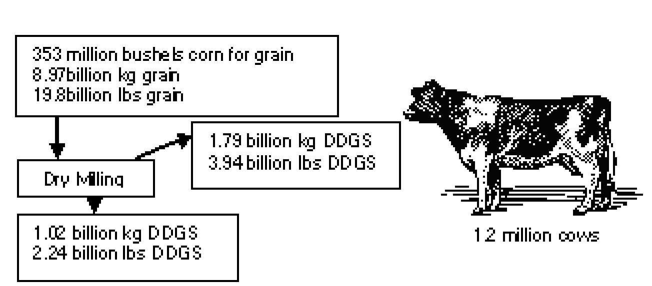

Figure 1. Potential Mass Flow of DDGS to Wisconsin's dairy herd based on 20% DMI of DDGS.

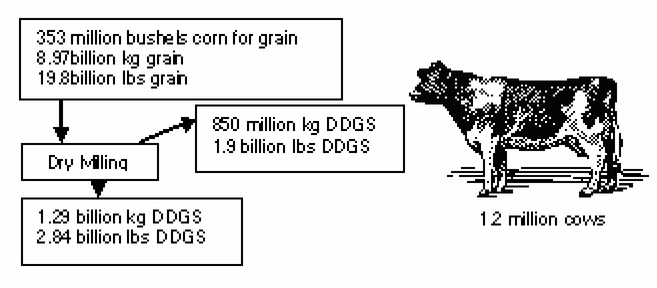

Figure 2. Potential mass flow of DDGS to Wisconsin's dairy herd based on 10% DMI of DDGS.

Ethanol has approximately 68% the energy value of petroleum gasoline (derived from Wisconsin Department of Administration, 2004). Therefore, the production of 2.22 billion liters (586 million gallons) or 1.07 billion liters (282 million gallons) of ethanol, produced to meet the annual input of 20% and 10% DDGS DMI for all Wisconsin dairy cows, has the energy equivalent of about 1.50 billion liters (396 million gallons) and 719 million liters (190 million gallons) of petroleum gasoline, respectively. Using 2.22 billion liters of ethanol in place of 1.50 billion liters of gasoline could have replaced approximately 15% of the gasoline used in Wisconsin in 2003. Replacing 719 million liters of gasoline with 1.07 billion liters of ethanol could substitute about 7% of the gasoline used annually in Wisconsin, based on statewide gasoline consumption in 2003 (Wisconsin Department of Administration, 2004). It should be noted that comparing energy content of fuel considers fuel efficiency and not engine performance. Actual petroleum fuel replacement by ethanol or biodiesel would likely be larger than estimates given.

Impacts of Maximizing Soybean Meal in Wisconsin Dairy Rations on Biodiesel Production

Just as in the previous discussion of using DDGS from ethanol production in the Wisconsin dairy ration, soybean meal maximization in dairy rations is discussed here as a basis for biodiesel production. Allowable soybean meal consumption by a dairy cow ranges from 2.04 kg/day (4.50 lbs/day) in a diet containing mostly alfalfa as forage to 2.70 kg/day (5.95 lbs/day) for a ration containing mostly corn silage as forage (based on model diets created with Nutrient Requirements of Dairy Cattle, Clark et. al., 2000). Therefore, maximizing annual soybean meal consumption for Wisconsin's dairy herd requires from 894 million kg (1.79 billion lbs) to 1.18 billion kg (2.61 billion lbs) of soybean meal per year. The average amount of soybean meal allowable for the Wisconsin dairy herd is about 1.04 billion kg (2.07 billion lbs) per year. Utilizing all of the soybean oil from the state's soybean production for making biodiesel would produce about 1.2 billion kg (2.6 billion lbs) soybean meal. Figure 3 shows the amount of soybean meal that could be produced from the state's soybean crop is more than enough to feed all of the Wisconsin dairy cows based on a statewide consumption of 1.04 billion kg/year.

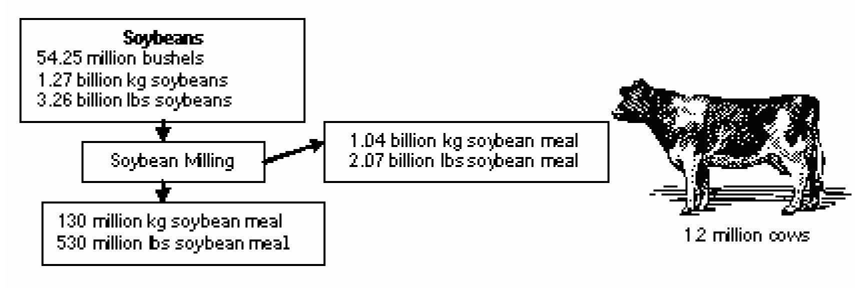

Figure 3. Potential mass flow of soybean meal produced from Wisconsin's soybean meal crop.

Producing 1.04 billion kg (2.07 billion lbs) of soybean meal yields enough oil to allow for the production of about 264 million liters (69.7 million gallons) of biodiesel. (It should be noted that soybean oil has various other uses, and dedicating all the soybean oil yielded by crushing done to produce soybean meal may therefore be unlikely). Biodiesel has approximately 89% the energy value of petroleum diesel (Radich, 2004). 264 million liters (69.7 million gallons) of biodiesel could replace, considering fuel efficiency and not engine performance, 235 million liters (62.0 million gallons), or about 6.0% of petroleum diesel used in the state in 2003 (Wisconsin Department of Administration, 2004).

Impacts of Maximizing Both DDGS and Soybean Meal in Wisconsin Dairy Rations on Ethanol and Biodiesel Production

The contribution of DDGS to dairy rations is often considered as a replacement for soybean meal (Schingoethe et. al., 2002). The use of soybean meal in a dairy diet limits the use of DDGS because both feeds concentrate the crude protein content of rations. Therefore, when maximizing both soybean meal and DDGS in dairy diets, they are considered in the same proportion. Although research has shown DDGS can function as a substitute for soybean meal and corn in dairy cow diets, it has a low content of an essential amino acid, lysine, which limits its use (Armentano, 1996). Blood meal has been used for lysine supplementation in dairy diets which contain DDGS (Stallings, 1997). Blood meal is included in the model rations which maximize the use of DDGS. Three proportions of DDGS and soybean meal use in dairy rations were modeled according to nutrient requirements when considering three different forage ratios. Three model diets were considered with the following DDGS and soybean meal contents: using both 4% DDGS DMI and 4% soybean meal DMI in one diet, a combination of 6% DDGS DMI with 6% soybean meal DMI in a second diet, and 9% DDGS DMI with 9% soybean meal DMI in a third diet. Model diets, along with the respective ethanol or biodiesel coproduction needed to meet DDGS and soybean meal needs, are presented in table 1. The amount of gasoline and petroleum diesel that could be replaced by corn ethanol and soy biodiesel, based on fuel energy content, is given in table 2.

Energy Balance of Feed Production and Biofuel Credits

Ration components of model diets are given in table 3. Energy inputs for producing feed crops, such as corn, vary by author. Select feeds used for rations modeled in this paper are listed, along with the primary energy required for their production in table 4.

Table 1. Biofuel production based on the combined use of Soybean meal and DDGS in dairy rations.

DDGS and Soybean Meal Use (%DMI of Each DDGS & Soybean Meal)	Soybean Meal DMI per Year for WI's 1.2 Million Dairy Cows (million kg)	Annual Biodiesel Production Coproduced to Meet Annual Soybean Meal Consumption (million liters)	DDGS DMI per Year for WI's 1.2 Million Dairy Cows (million kg)	Annual Ethanol Production Coproduced to Meet Annual DDGS Consumption (million liters)
4%	500	128	500	606
6%	298	76.5	298	362
9%	767	197	767	931

Table 2. Possible petroleum fuel displacement in Wisconsin from utilizing both DDGS and soybean meal from ethanol and soy biodiesel production.

Ration Name	DDGS Use in Ration (%DMI)	Soybean Meal Use in Ration (%DMI)	Possible Annual Gasoline Displacement by Ethanol, Based on Fuel Energy Content (million liters)	Possible Annual Gasoline Displacement by Ethanol, Based on Fuel Energy Content (% of gasoline used in WI in 2003)	Possible Annual Petroleum Diesel Displacement by Biodiesel, Based on Fuel Energy Content (million liters)	Possible Annual Petroleum Diesel Displacement by Biodiesel, Based on Fuel Energy Content (% of diesel used in WI in 2003)	Total Annual Petroleum Displacement by Ethanol and Soy Biodiesel Coproduced for Dairy Rations (% of Btu's consumed as gasoline and diesel fuel in 2003)
DDGS and Soybean Meal B	4%	4%	244	2.5	67.4	1.8	2.3
DDGS and Soybean Meal A	6%	6%	409	4.2	113	2.9	3.8
DDGS and Soybean Meal C	9%	9%	628	6.5	173	4.5	5.9

Table 3. Ration composition of model diets (% DMI).

Ration Name [a]	Alfalfa Haylage	Corn Silage	Corn Grain	Tallow	DDGS	Soybean Meal	Vitamin Premix	Limestone	Blood Meal
Baseline A	29%	36%	21%	1%	0%	11%	1%	1%	0%
Baseline B	49%	16%	26%	1%	0%	6%	1%	1%	0%
Baseline C	16%	49%	18%	1%	0%	14%	1%	1%	0%
10% DDGS A	37%	28%	17%	0%	10%	3%	2%	2%	1%
10% DDGS B	47%	16%	20%	0%	10%	0%	3%	3%	1%
10% DDGS C	16%	48%	11%	0%	10%	8%	3%	3%	1%
20% DDGS A	26%	26%	21%	0%	20%	0%	2%	2%	2%
DDGS and Soybean Meal A	35%	28%	20%	0%	6%	6%	2%	2%	1%
DDGS and Soybean Meal B	46%	16%	27%	0%	4%	4%	1%	1%	1%
DDGS and Soybean Meal C	15%	46%	16%	0%	9%	9%	2%	2%	1%

[a]Diets were formulated according to NRC recommendations, University of WI-Madison dairy nutritionist recommendations (Wattiaux and Armentano, Personal Communication, 2005) and crude protein content. A, B, C represent potential variations in forage composition.

Table 4. Primary input energy needed to produce these dairy feeds.

Crop	Energy Input kcal/kg	Source
Corn in Wisconsin	954	Pimentel, 1980
Corn Silage	597	Pimentel, 1980
Alfalfa	498	Pimentel, 1980
Soybean Meal (not including conversion of oil to biodiesel)	3,283	Pimentel, 1980 & Sheehan et. al., 1998
Soybean Meal (including conversion of oil to biodiesel)	3,993	Pimentel, 1980 & Sheehan et. al., 1998
DDGS (including conversion of starch to ethanol)	6,113	Pimentel, 1980 & Shapouri et. al., 2001

The estimates for energy required for the production of corn, corn silage, and alfalfa were obtained from the CRC Handbook of Energy Utilization in Agriculture (Pimentel, 1980) for agricultural inputs used in, or near Wisconsin. Energy input into the making of biofuel production coproducts were computed from the energy input to growing the crop (Pimentel, 1980) combined with the process energy input for making DDGS from corn (Shapouri et. al., 2004) and soybean meal from soybeans (Sheehan et. al., 2004).

The energy input for the fraction of the ration including tallow, vitamin premix, limestone and blood meal are not considered in this evaluation as the energy input to their production is difficult to predict, not prevalent in the literature, and contributes a small part of the total ration (tallow, vitamin premix, limestone and blood meal contribute from about 2.9% to 6.8% of the model rations). Primary energy inputs to model rations are shown in table 5.

Table 5. Approximate primary energy input into ration feed production. Note blood meal, limestone, tallow, and vitamin premix energy input values are not included.

Baseline Rations [a]	Energy Input (kcal/daily ration/cow)	Energy Input (GJ/daily ration/cow)
Baseline A	17,800	0.075
Baseline B	17,200	0.072
Baseline C	19,400	0.081
Diets Containing DDGS [a]		
20% DDGS A	32,900	0.138
10% DDGS A	23,600	0.099
10% DDGS B	22,300	0.093
10% DDGS C	26,500	0.111
Diets Maximizing Soybean Meal [b]		
Baseline A	19,300	0.081
Baseline B	18,600	0.078
Baseline C	21,300	0.089
Maximizing both DDGS and Soybean Meal [b]		
DDGS and Soybean Meal A	22,000	0.092
DDGS and Soybean Meal B	19,000	0.080
DDGS and Soybean Meal C	27,300	0.114

[a] Energy input for soybean meal does not include energy input to biodiesel production.
[b] Energy input for soybean meal includes energy input to biodiesel production.

The energy inputs required to produce the model rations for the entire 1.2 million cow dairy herd in Wisconsin are listed in the table 5. The amount of energy input into the rations was credited with the energy content of the appropriate liquid fuel produced. For example, if DDGS is part of model ration, then the energy input to produce that ration was credited with the energy content of the ethanol distilled to coproduce the amount of DDGS used in that diet. Table 6 lists the difference between energy required to produce rations credited by the energy coproduced as liquid fuel output. (Note: the baseline diets were not designated a biofuel production energy credit). The energy input into biofuel production was considered when summing energy input into making rations that contain DDGS and/or soybean meal. Otherwise, the energy input into producing soybean meal alone, without the energy input into oil conversion to biodiesel, was considered when biodiesel was not included in the difference.

Table 6. Annual energy balance of energy input to producing feeds versus energy output of fuels produced by using DDGS and/or soybean meal.

Baseline Rations [a]	**Annual Input Energy to Rations for 1.2 Million Dairy Cows (GJ/year)**	**Energy Contained in Biofuel Equivalent to DDGS and/or Soybean Meal Used in Ration (GJ/year)**	**Difference Between Energy Input to Ration and Energy Content of Fuel (GJ/year)**
Baseline A	32,600,000	0	32,600,000
Baseline B	31,500,000	0	31,500,000
Baseline C	35,500,000	0	35,500,000
Diets Containing DDGS [a]			
20% DDGS A	60,300,000	52,200,000	8,100,000
10% DDGS A	43,300,000	25,100,000	18,200,000
10% DDGS B	40,900,000	25,100,000	15,800,000
10% DDGS C	48,600,000	25,100,000	23,500,000
Diets Maximizing Soybean Meal [b]			
Soybean Meal A	35,400,000	8,140,000	27,260,000
Soybean Meal B	34,200,000	7,800,000	26,400,000
Soybean Meal C	39,100,000	10,300,000	28,800,000
Maximizing both DDGS and Soybean Meal [b]			
DDGS and Soybean Meal A	40,300,000	18,700,000	21,600,000
DDGS and Soybean Meal B	34,900,000	11,100,000	23,800,000
DDGS and Soybean Meal C	50,000,000	28,700,000	21,300,000

[a] Energy input for soybean meal does not include energy input to biodiesel production.
[b] Energy input for soybean meal includes energy input to biodiesel production.

The comparison of energy input to making the feeds used in model rations to the energy of the biofuel that can be produced based on the amount of DDGS and/or soybean meal used in the rations require less overall energy than the baseline diets, in which no biofuel product is considered. Table 5 shows that feeding a nutritionally adequate ration to Wisconsin's dairy herd that contains soybean meal or DDGS coproduced from biofuel production, and crediting the energy contained in these biofuels, lowers the overall energy input to create dairy rations for the state.

Using Feed Prices to compare cost of Dairy Rations

The Economic Research Service of the United States Department of Agriculture (2005) provides historical reports of feed commodity prices. Data from these reports were used to find the average prices and the fluctuation in these commodity prices, for soybean meal, distillers dried grain, and corn grain using available data from the Economic Research Service of the United States Department of Agriculture. The average price for soybean meal out of Decatur, Illinois from 1999-2005 is $188.95/ton with a standard deviation of $38.41/ton. Distillers dried grain prices from Lawrenceburg, Indiana from 1999-2005 average $87.02/ton with a standard deviation of $17.70/ton. Corn prices from 2002 to 2005, average to be $2.24 per bushel, or about $80 per ton. The average prices of soybean meal and corn distillers grains, as well as the prices of other feeds used in the rations presented in this thesis are presented in table 7. These prices were used along with the intake consumed of each feed for the rations evaluated in this study. The types of diets along with their feed cost per day are given in table 8.

Table 7. Prices considered when calculated costs of model rations.

Feed	Price as Fed ($/ton)	Price as Dry Matter ($/ton)	Source of Price
Alfalfa Haylage	110.04	110.04	Average price prime grade large bale (Barnett, 2004)
Corn Silage	22.40	22.40	Price of corn/bushel (ERS, USDA, 2002-2005) x 10 (Lauer & Undersander, 2004)
Corn Grain	80.00	90.80	ERS, USDA, 2002-2005
Tallow	400.00	400.00	USDA Tallow, Protein and Hide Report - Central U.S., November 2005 based on $20.00/hundredweight
Vitamin Premix	540.00	540.00	Howard & Shaver, November 1997 based on $27/cwt
Limestone	140.00	140.00	Howard & Shaver, November 1997 based on $7/cwt
Blood Meal	474.00	525.00	University of Missouri Extension, Pork blood meal, Fairway Dairy and Ingredients, Lakeville, MN, November 2005
Soybean Meal	188.95	211.00	Average price from 1999-2005 in Decatur, Illinois (ERS, USDA, August 2005)
Corn Distillers Grains	87.02	96.50	Average price from 1999-2005 in Lawrenceburg, Indiana (ERS, USDA, August 2005)

Table 8. Approximate cost of rations modeled in this thesis.

Baseline Diets [a]	Cost ration/day	
Baseline A	$1.98	
Baseline B	$2.34	
Baseline C	$1.81	
Diets Containing DDGS	**Cost ration/day**	**Difference Compared to Baseline**
20% DDGS A	$2.13	$0.13
10% DDGS A	$2.13	$0.15
10% DDGS B	$2.27	-$0.07
10% DDGS C	$1.88	$0.07
Diets Maximizes Soybean Meal & DDGS		
DDGS and Soybean Meal A	$2.14	$0.15
DDGS and Soybean Meal B	$2.19	-$0.15
DDGS and Soybean Meal C	$1.87	$0.06

[a] These costs of these diets also represent those diets which maximize soybean meal in the ration.

Considering the data presented in table 8, it appears that maximizing use of DDGS or soybean meal in dairy diets is usually more costly on a per ration basis than the baseline diets. The exceptions are diet 10% DDGS B and diet DDGS and Soybean meal B, which are $.0.07 and $0.15 less expensive than comparable baseline diets, respectively. Although DDGS is less expensive than soybean meal on a per ton basis, using DDGS requires supplementation of blood meal in order to meet amino acid requirements of the dairy cow. This supplementation causes most daily rations that include DDGS to be more expensive than the baseline diets which do not contain any DDGS. Overall, if historical prices are assumed, the maximization of DDGS and/or soybean meal appears to be a disincentive to using DDGS and/or soybean meal, as these rations are more expensive than baseline model rations. One should also consider if the production of ethanol continues to increase, the quantity of DDGS will rise, and its price would likely decrease.

Conclusion

Opportunities exist for integration of corn ethanol production and soy biodiesel production and the dairy industry. Soybean crushing yields soybean meal, which is used to supplement crude protein intake of dairy cows, as well as soy oil which can be processed into biodiesel. DDGS, a byproduct of ethanol production may also contribute to dairy feed rations as a protein supplement. Considering the nutritional needs of the Wisconsin dairy herd, biofuel production based on the maximum amounts of DDGS and soybean meal allowable to dairy rations was calculated. It was found that about 15% of the energy consumed as gasoline in Wisconsin could be replaced by ethanol based on maximum allowable DDGS consumption by the state's 1.2 million dairy cows. Biodiesel production, based on maximum allowable soybean meal consumption by the state's dairy herd, could replace approximately 6.0% of the petroleum diesel used in Wisconsin. Combined use of DDGS and soybean meal in the state's dairy rations could replace about 5.9% of the energy currently consumed as gasoline and petroleum diesel fuels in Wisconsin. Using DDGS and soybean meal from ethanol and biodiesel production, respectively, provides an energy credit to the overall energy balance of producing feeds. Rations which maximize the use of DDGS and/or soybean meal are typically more expensive, based on historic market prices, than diets which do not maximize these components. The energy credits given based on ethanol and biodiesel production may not be realized unless DDGS and/or soybean meal prices become more economically competitive to prices of feeds currently used in dairy rations.

Acknowledgements

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