PRESERVATION AND FEEDING OF WET DISTILLERS GRAINS TO DAIRY CATTLE

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INTRODUCTION

Distillers' grains continue to be one of the most readily available co-products in use in the Midwest. Its price is driven not only by that of other concentrate feeds (such as corn and soybean meal) but also by supply and demand. Its popularity has increased in recent years among dairy producers, grain elevators, and nutritionists due to its high nutrient density, competitive price, and availability. The high concentration of protein, fiber, and fat resulting from the removal of the starch are the reasons for this increased nutrient concentration and improved animal performance. Ethanol plants usually sell wet and/or dried distillers' grains (DDG), and are usually built in corn growing areas, relatively close to large dairy producers. Wet distillers' grains (WDG) are fed to dairy cattle located in relative proximity to these plant whereas DDG are fed locally or can be exported to almost everywhere in the world. The current increase in ethanol production and distillers' grains availability is spurred by raising fossil fuel costs. Using WDG locally makes thus more sense from an energy efficiency standpoint than drying and transporting DDG. Furthermore, the application of heat during the drying process of DDG entails the possibility of heat damaging the protein, which reduces nutrient availability. Preservation issues, both at the ethanol production plant and the farm have been the main constraints that prevent the widespread use of WDG. Due to the increased risk of spoilage ethanol plants do not want to wait unnecessarily before shipping WDG. Dairy producers need also to adjust the tonnage of WDG received to the number of animals to be fed or use storage methods that preserve the quality of the product. This paper will discuss issues related to the conservation and the use of wet distillers' grains fed to dairy cattle.

CARACTERIZATION OF DISTILLERS GRAINS

I. Nutrient content

Although corn processing for ethanol production is not the focus of this paper, there are some unique characteristics of this co-product that need to be briefly addressed in order to understand the benefits as well as potential constraints of its use.

During the ethanol production process ground corn grain is fermented in vats by adding the yeast Saccharomyces cerevisiae under controlled conditions. As a result of this fermentation ethanol is produced, and most of the starch is removed, which concentrates all other nutrients by approximately three-fold (Table 1).

An exception to this “three-fold” rule is its sulfur content as corn has originally 0.10% whereas distillers grains may have up to 1%. The reason for this “discrepancy” arises from the ethanol-extraction process itself, and is the result of the addition of sulfuric acid to stop the fermentation process.

Table 1. Composition of distillers’ grains and corn (dry matter basis).

Item	Corn	Distillers grains	TM* distillers grains
CP	9.1	29.7	30.3
NDF	9.5	38.8	29.6
ADF	3.4	19.7	12.9
Fat	4.2	10	11.6
Ca	0.04	0.22	0.04
P	0.3	0.83	0.81
S	0.1	0.44	0.74
Ash	1.5	5.2	4.4

*TM = Trade marked DDG.
Source: NRC. Nutrient requirements of dairy cattle 2001.

II. The pH of WDG

The addition of acid at the end of the ethanol-production process results in a very low pH in WDG. This is an interesting property that has its importance for storing purposes. Analyses of fresh as well as bagged and ensiled WDG have shown pH values consistent and stable over time (Table 2).

Table 2. Fermentation pattern in ensiled WDG.

			Day			
Item	**0**	**3**	**7**	**14**	**129**	**SEM**
pH	3.1	3.1	3.2	3.2	3.1	0.04
	---------------------------% DM-----------------------------					
Acetic acid	0	0	0.11	0.30	0.23	0.16
Propionic acid	0.30	0.30	0.32	0.30	0.33	0.02
Lactic acid	0.90	0.95	0.97	1.02	0.98	0.02

Source: Kalscheur et al. 2002

Silage fermentation has traditionally been divided into 4 phases: the first one or aerobic phase, the second one dominated by microbial activity, acid production and rapid pH drop, a third one where low pH inhibits proliferation of bacteria, and a fourth one during feed out and exposure to air. Whenever WDG are mixed with other feeds the pH of the blend decreases immediately. The initial pH of the blend results from the low pH of WDG neutralized to a variable extent by the original pH of the other feed before any significant fermentation can take place (Table 3).

Table 3. pH changes over time in corn silage, WDG, and their blends.

Day	Corn silage	75% CS:25% WDG	50% CS:50% WDG	WDG
	--pH--			
0	5.6	4.6	3.9	3.1
3	3.7	3.6	3.8	3.1
7	3.7	3.6	3.9	3.2
14	3.7	3.7	3.8	3.2
129	3.7	4.0	3.9	3.1

Source: Kalscheur et al. 2003

III. Aerobic stability of WDG blends

Recent research at SDSU focused in combining the increasingly available WDG with corn silage in an attempt to improve the preservation of both feeds. Aerobic deterioration can make it difficult to preserve WDG as oxygen enhances yeast growth during storage. On the other hand, frozen WDG preserved in a silo bag can be difficult to remove for feeding during the cold winter months. Blending both feeds resulted in increased aerobic stability as well as ease of removal during cold weather as the longer particles break more easily. Aerobic stability was measured as the number of hours it took for the feed to increase its temperature by 2 ^{O}C above that of ambient temperature. Corn silage and WDG were ensiled together at 75:25 and 50:50 ratios by weight. The initial pH of both blends upon mixing and before bagging was 4.6 and 4.0 for the 75 and 50% corn silage respectively. The chopped corn plants had a pH of 5.7, whereas that of the straight WDG was 3.1. As the initial measurements were taken immediately after mixing, the pH drop resulted from the pH of the WDG rather than of any fermentation process taking place. By day 129 the pH of the blends was still 4 or less for the individual feeds and their blends (Table 4).

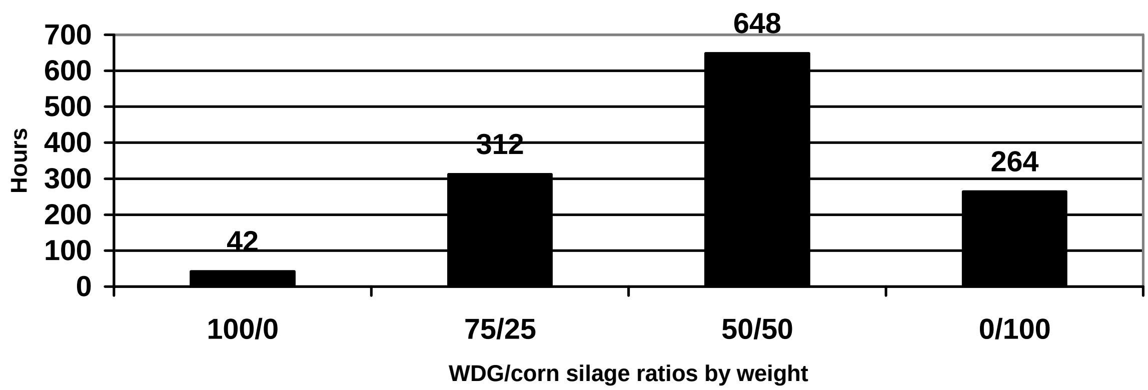
Table 4. Chemical composition of the blends after 129 days of ensiling.

	Corn silage:Wet Distillers Grains ratio			
Item	**100:0**	**75:25**	**50:50**	**0:100**
pH	3.7^{b}	4.0^{b}	3.9^{ab}	3.1^{c}
DM	27.6^{b}	28.6^{ab}	30.0^{ab}	30.8^{a}
CP	10.6^{d}	16.7^{c}	23.6^{b}	30.7^{a}
NDF	45.5	45.3	43.1	38.2
ADF	27.3^{a}	24.0^{b}	20.9^{c}	20.7^{c}
Aerobic stability	42^{c}	312^{b}	648^{a}	264^{b}

^{abcd} Means in rows with unlike superscripts differ ($P < 0.05$).
Source: Kalscheur et al. 2003.

The corn silage/WDG blends greatly improved aerobic stability upon exposure to air when compared to corn silage alone. Mixing WDG with corn silage at 50 % by weight more than doubled the aerobic stability of the other blend (Graph 1).

Graph 1. Aerobic stability of WDG, corn silage and their blends



A subsequent trial measured organic matter losses when WDG were blended with wet beet pulp (Kalscheur et al. 2004). Ash was used as a marker to measure organic matter losses. By day 112 of ensiling organic matter losses of wet beet pulp ensiled alone were 15.3 %. When WDG were blended at 33 and 66%, organic matter losses were 10.0 and 7.9%, respectively. These results support previous findings and suggest that the low initial pH of the WDG favors a hetero-fermentative type of fermentation when other substrates are present.

FEEDING WET DISTILLERS GRAINS TO GROWING DAIRY HEIFERS

When rearing dairy heifers, one must be cautious of excessive weight gains, which might result in over-conditioning. The National Research Council's Nutrient Requirement of Dairy Cattle (NRC, 2001) recommends that heifers gain on average 1.9 lbs per day to attain recommended size at calving (23 to 24 months of age). Excessive weight gains result in fat deposits in the udder. This results in reductions in milk production in subsequent lactations, and increases the incidence of calving difficulty and metabolic disorders. Monitoring growth is thus very important when establishing a feeding program for replacement heifers. Varying the nutrient density of the diet regulates growth and weight gain. The inclusion of highly digestible feeds in balanced diets results in more available energy that accelerates growth. In over-conditioned heifers, dietary energy needs to be limited, either by restricting the amount of feed offered or by adding low-energy feeds such as crop residues (straw and corn stalks) to the diet. Poor quality forages with a high NDF fraction of low digestibility usually limits intake due to their "fill effect." These forages can be incorporated into diets to limit total intake. When balancing diets, it is important to consider not only the amount of grain or starch included in the diet but also the quality of the roughage supplied. Feeds high in fiber can supply variable energy depending on their digestibility.

Since WDG provide more protein, fat, sulfur, and phosphorus than what is required by growing dairy heifers, a good combination are low quality, high fiber feeds such as crop residues. Corn stalks or straw thus make excellent alternatives to explore. When blended together at adequate amounts, these feeds can provide adequate nutrient concentrations by balancing the excesses of one with the deficits of the other. Researchers at SDSU fed a WDG-corn stalk blend to evaluate growth characteristics of dairy heifers compared to heifers fed traditional diets. Heifers were fed either a traditional diet consisting of alfalfa and grass hays, alfalfa haylage, corn silage, DDG, earlage, and a mineral/vitamin pack, or a second diet that consisted of 86% of a blend of 69% WDG ensiled with 31% corn stalks, rye straw, minerals, and vitamins. Both diets were formulated for similar nutrient concentrations on a dry matter basis: 0.41 Mcal NEg/lb, 18.6% protein, 25% ADF, and 37% NDF. Fat was higher in the treatment diet (10.5%) than the control diet (5.1%) resulting from an unusually high fat concentration (20%) in WDG. In spite of this difference, heifers fed the traditional diet gained more weight than those on the diet with the WDG/corn stalks blend (2.82 vs. 2.31 lb/d); however, both were greater than recommended by the NRC. The results of this trial suggest corn stalks and WDG can be incorporated successfully in heifer diets without negatively affecting growth.

FEEDING WET DISTILLERS GRAINS TO LACTATING DAIRY COWS

One of the main constraints that has been identified with distillers grains is the variability in nutrient content that exists between and sometimes even within ethanol plants. Variability as well as digestibility of certain individual nutrients is a matter of concern. Crude protein availability in particular can be affected by drying. During heating protein is bound with carbohydrates in what is known as non-enzymatic browning or Maillard reaction, which is determined in the laboratory as acid detergent insoluble nitrogen (ADIN or ADCP). In this reaction both protein and carbohydrates become unavailable to the animal decreasing the nutritive value of the feed. The Maillard reaction is function not only of the temperature and duration of the drying process but also of the moisture content of the feed. These are all parameters that differ to a variable extent between ethanol plants in WDG that is about to be dried. Field samples of DDG that came from 14 California dairies showed a CV% of the ADCP of 40.6% compared to only 8.8% from a sample that came from a single source (Robinson. 2005). If these differences are not accounted for and diets are not balanced for their RUP/RDP content animal performance can be compromised to a variable extent.

In a recent study rumen degradability of DM and CP from soybean meal (SBM), DDG from five sources (A, B, C, D, and E) and one source of WDG were determined (Kleinschmit et al. 2005). As it could be expected ruminal DM and CP degradation rates were greater for SBM when compared with DDG. Ruminal DM degradation rate of WDG was greater compared with three of the DDG sources. Crude protein degradation rate of WDG was greater than four out of the five DDG sources. When comparing DG sources, WDG had less RUP than DDG (Table 5).

Table 5. Rumen and intestinal degradability of DM and protein of different sources of DDGS and WDG.

Treatment	**SBM**	**A**	**B**	**C**	**D**	**E**	**W**
DM degrad./h	0.0858^{a}	0.0209^{c}	0.0237^{c}	0.0261^{bc}	0.0232^{c}	0.0274^{bc}	0.0334^{b}
CP degrad./h	0.0852^{a}	0.0134^{c}	0.186^{c}	0.0214^{c}	0.0161^{c}	0.0256^{bc}	0.0340^{b}
RUDM,%	29.4^{d}	57.0^{a}	53.8^{b}	52.0^{bc}	56.6^{a}	51.1^{bc}	50.8^{c}
RUP,%	38.9^{c}	78.0^{a}	67.8^{b}	63.6^{c}	71.0^{b}	63.5^{c}	56.5^{d}
ID,%	87.5^{a}	62.5^{d}	77.4^{b}	77.4^{b}	66.1^{cd}	65.9^{cd}	71.7^{bc}

^{abcde} Means in rows with unlike superscripts differ (P<0.05).
Kleinschmit et al. 2005.

These results show that the drying process to which DDG was subjected clearly affected its degradability and thus the nitrogen supply to the rumen microbial population. This can even have a greater impact if rate of passage is accelerated by increased feed intake, reduced ration particle size, and/or inadequate rumen mat formation. Intestinal digestibility (ID) of SBM was greater than all DDG sources. This suggests that the amino acid supply and uptake by the small intestine would be greater with SBM than with DDG when similar amounts of both escape rumen degradation. There were no differences in the ID of WDG when compared to DDG, except for one source (A) which was lower. The lower RUP in SBM when compared to DDG can ensure a greater supply of fermentable nutrients needed for optimal growth of rumen microbes, particularly in high producing dairy cows. In this trial RDP was 61.1% for SBM and 43.5% for WDG. This means that each kg of SBM and WDG consumed by the cow supplies respectively 389 g and 561g of protein to the intestines. When corrected for ID, SBM and WDG would supply respectively 340g and 402 g of protein to the intestines. In cows of moderate production (e.g. later in lactation) the nitrogen requirements of the rumen microbial population as well as the amino acid requirements of the host can more than likely be covered by supplementing with WDG.

This was confirmed in a recent study (Mpapho et al. 2005) that evaluated production, intake, and milk composition of dairy cows in early lactation fed WDG at 15% of the diet dry matter. Diets contained 35% corn silage and 15% alfalfa hay on a DM basis. The treatment group was fed WDG at 15% of the diet DM. In the control diet, WDG was replaced by corn grain, SBM, and extruded and expeller soybean meals. Diets were balanced for 17% CP, 21.7% forage, 5.5% ether extract, and 1.63 Mcal NEL/kg and offered for ad libitum intake. There was no difference in dry matter intake, milk production or components of cows fed WDG or control suggesting WDG can be fed at 15% of the diet dry matter without affecting lactation performance.

Hippen et al. (2003) evaluated the effects of increasing WDG in dairy cow diets. The WDG was included at 10, 20, 30, or 40% of the diet DM in replacement of soybean meal, soybean hulls, and animal fat as inclusion rates increased (Table 6).

Nutrient composition of the diets are in Table 7. Diet DM decreased (46.9, 43.9, 39.4, and 36.5%) as WDG in the diets increased. Dry matter intakes decreased as WDG in the diet increased (22.9, 23.0, 19.4, and 17.2 kg/d; $P < 0.01$). Milk production also decreased (27.3, 26.9, 25.0, and 25.5 kg/d; $P < 0.05$) with increasing concentrations of WDG in the diet. Milk component concentrations did not change with diets; however, milk fat yield (0.72, 0.72, 0.68, and 0.67 kg/d), lactose (1.28, 1.25, 1.20, and 1.18 kg/d), and urea nitrogen (41.4, 40.2, 38.9, and 35.7 g/d) decreased ($P < 0.05$) when WDG increased in the diets. Increasing WDG above 20% of dry matter in diets of lactating dairy cows decreased DMI and yield of milk and milk components.

Table 6. Ingredient composition of diets.

Item	WDG in diet, % DM 10	20	30	40
	----------% DM----------			
Corn silage	30	30	30	30
Brome hay	15	15	15	15
WDG	10	20	30	40
Corn grain	15	14	13	12
Extruded soybeans	8.2	5.4	2.7	---
44% soybean meal	8.0	5.3	2.7	---
Soybean hulls	7.7	5.1	2.6	---
Soyplus	1.6	1.1	0.6	---
Animal fat	1.6	1.1	0.6	---
Min and vit.[1]	3.1	3.1	3.1	3.1

[1] Contains: calcium carbonate, 22.6%; sodium bicarbonate, 11.3%; Land O'Lakes Dairy Micro Premix, 5.3%; Diamond V XP Yeast, 4.2%; magnesium oxide, 2.6%; Zinpro 4-Plex, 1.0%; and Land O' Lakes Vitamin E20, 0.6%.

Table 7. Nutrient Composition of Diets[1].

Item	WDG in diet, % DM 10	20	30	40
NEL, mcal/kg	1.65	1.65	1.65	1.65
Item	----------% DM----------			
Dry matter	46.9	43.8	39.4	36.5
Crude protein	17.9	18.0	18.0	18.0
RDP	10.3	10.0	9.7	9.4
RUP	7.7	8.0	8.3	8.5
NDF	36.0	37.9	39.7	41.5
Forage NDF	22.8	22.8	22.8	22.8
ADF	20.9	20.9	20.9	20.9
Ether Extract	6.5	6.5	6.5	6.6
Calcium	0.79	0.78	0.77	0.75
Phosphorus	0.39	0.42	0.46	0.49

[1] Calculated based upon chemistry of individual feedstuffs and NRC (2001) values.

In this experiment feeding WDG at concentrations greater than 20% of diet DM depressed feed intake and milk production of lactating cows. On the other hand, feed efficiency of ECM production increased as WDG in the diet increased. Percentage of protein and fat was not affected by diets; however, protein and fat concentrations in milk from cows on all treatments were inverted. High diet moisture content from fermented feedstuffs may have negatively impacted rumen fermentation and milk fat production in all cows fed WDG in this experiment.

Similar results were reported by Ladd (2005) where the performance of cows fed either WDG or DDG both on a supplemental in situ trial as well as a lactation trial was evaluated. The objective of the in situ trial was to characterize the differences of digestibility between the sources of DDG and WDG used based on DM, CP, and NDF degradations. In this trial RUP as a % of the CP was 63.50, 56.54, and 38.92% for DDG, WDG, and SBM, respectively (Table 8). Total digestible protein showed SBM as having the highest value with 94.93%, followed by WDG with 84.07%, and DDG with 78.39% (Table 9).

Table 8. Rumen disappearance rate of different feed fractions.

Item	SBM	DDG	WDG	SEM
DMD rate[1], /h	0.086[a]	0.027[a]	0.033[a]	0.007
CPD rate[1], /h	0.085[a]	0.026[a]	0.034[a]	0.007
NDFD rate[1], /h	-	0.027[b]	0.031[a]	0.004
RDDM[2]	70.66[a]	48.89[b]	49.18[b]	2.07
RDP[2], % of CP	61.08[a]	36.50[c]	43.46[b]	2.38
RUDM[3]	29.34[b]	51.11[a]	50.82[a]	2.07
RUP[3], % of CP	38.92[c]	63.50[a]	56.54[b]	2.39

[1] Fractional degradation rates.
[2] Ruminally degradable dry matter (RDDM) and ruminally degradable protein (RDP).
[3] Estimated ruminally undegradable dry matter (RUDM) and ruminally undegradable protein (RUP) determined by the following calculation: 100 – RDDM or 100 – RDP.
[abc] Means in rows with unlike superscripts differ ($P<0.05$).

Table 9. In vitro intestinal measures.

Item	SBM	DDG	WDG	SEM
ID[1], % of RUP	87.48[a]	65.85[b]	71.67[b]	3.74
IADP[2], % of CP	33.85[b]	41.89[a]	40.61[ab]	2.40
TDP[3], % of CP	94.93[a]	78.39[c]	84.07[b]	2.48

[1] Intestinal degradation (ID) after 12 h incubation in rumen in polyester bag and pepsin-pancreatin digestion.
[2] Intestinally absorbable dietary protein (IADP) (percentage of CP) = RUP (percentage of CP) x intestinal CP digestion (percentage of RUP).
[3] Total digestible protein (TDP) = RDP + IADP.
[abc] Means in rows with unlike superscripts differ ($P<0.05$).

In the lactation experiment the performance of cows fed diets containing DDG or WDG or corn w/ SBM (control) was evaluated. The diets that contained both forms of DG included them at 0% (control), 10%, or 20% of the DM. Both DDG and WDG were purchased from the same plant. Diet formulation and actual analyses are in Tables 10 and 11.

Feed efficiency was calculated as ECM/DMI and it was 1.70, 1.79, 1.87, 1.84, and 1.92 for control, 10%DDG, 20% DDG, 10% WDG, and 20% WDG, respectively. In summary, this trial found that digestibility of DDG and WDG were very similar, with the exception of CP. Cows fed the DG diets had better lactation performance than those fed the Control diet, with no differences found between WDG or DDG containing diets. There were trends for the cows fed 20% DG diets to have higher milk protein yields as well as higher feed efficiency when compared to cows fed diets with 10% DG. This again suggest that the optimum supplementation level with either DDG or WDG is somewhere between 10 and 20% of the diet dry matter. This optimum might be modified depending on the feeds that constitute the rest of the diet.

Table 10. Lactation trial diets.

	Diets				
Item	**Control**	**10% DDG**	**20% DDG**	**10% WDG**	**20% WDG**
	---% DM---				
Corn silage	25.00	25.00	25.00	25.00	25.00
Alfalfa hay	25.00	25.00	25.00	25.00	25.00
Corn grain	35.57	31.29	26.69	31.29	26.69
SBM,44%CP	12.49	7.00	1.60	7.00	1.60
DDG	0.00	10.00	20.00	0.00	0.00
WDG	0.00	0.00	0.00	10.00	20.00
Vit. & min.	1.94	1.72	1.72	1.72	1.72

Table 11. Composition of diets.

	Diet				
Item	**C**	**10% DDG**	**20% DDG**	**10% WDG**	**20% WDG**
DM%	55.43	55.94	56.35	50.14	46.25
	---% of DM---				
CP	16.83	16.30	17.17	17.61	17.61
NDF	28.27	30.68	31.24	30.35	32.37
ADF	17.93	19.43	19.01	19.19	20.64
Lignin	2.13	2.83	3.16	2.66	2.90
EE	2.29	3.06	4.18	3.35	3.37
Ash	6.87	6.62	6.73	6.89	6.89
Calcium	0.78	0.72	0.70	0.86	0.76
Phosphorus	0.30	0.32	0.32	0.31	0.34
Magnesium	0.32	0.32	0.32	0.31	0.33
Potassium	1.14	1.1	1.01	1.08	1.02
Sulfur	0.20	0.27	0.33	0.28	0.34

CONCLUSIONS

Both DDG and/or WDG can replace part of the corn grain and soybean meal commonly used in dairy cattle diets. Both can be used up to 20% of the diet dry matter without significant differences in production performance. Concentration of milk fat and milk protein was greater in cows fed diets WDG. One of the constraints of feeding either form of distiller's grains is its high fat concentration, and caution must be taken not to exceed recommended dietary guidelines for this nutrient. If the diet contains other sources of fat (e.g. cottonseeds, tallow, soybeans, etc.) the total fat supplied in the diet needs to be taken into consideration. Particle size of the total mixed ration is more than likely one of the most important parameters to consider when balancing diets with high inclusions of WDG. One aspect that needs future consideration is the depression in feed intake that has been observed in diets that contain high concentrations of fermented feeds. Wet distillers' grains have a pH of approximately 3. When combined with other fermented feeds such as corn silage, alfalfa silage, and high moisture corn, the acidity of the total diet and/or the load of organic acids may negatively affect the pattern of rumen fermentation.

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