Evaluation of Distiller's Dried Grains with Solubles for Lactating Cows in Taiwan

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Introduction

Distiller's dried grains with solubles (DDGS) has been fed to cattle for more than a century. It is recognized as good protein supplement for ruminants. However, the quality of DDGS from different sources is variable. The old DDGS from whiskey distilling tends to be dark in color and lower in quality due to over-heating in the drying process. Improved efficiency of fermentation and drying processes in new fuel ethanol plants has resulted in higher nutrient content and less heat-damaged DDGS. The DDGS that is produced from the new ethanol production facilities in the Midwestern US contains more protein and fat than published older "book" values (Harty, et al., 1998). The fiber fraction of corn or DDGS is highly digestible (Chen, et al., 1999, Schingoethe, et al., 1999). Therefore, DDGS can be a good source of ruminally degradable protein (RDP), ruminally undegradable protein (RUP), and energy for ruminants (Schingoethe, et al., 1999). Fron et al. (1996) suggested that distiller's solubles can improve the capacity of the ruminal microorganisms to metabolize lactic acid and can selectively manipulate the ruminal microbial population. Animal performance may also be influenced by the unidentified factors in the solubles, in addition to protein, fiber, and fat present in the of distiller's grains fraction (Fron, et al., 1996).

DDGS has been shown to be as an excellent substitute for soybean meal and corn grain in dairy cow diets (Powers, et al., 1995, Schingoethe, et al., 1999). DDGS can support better (Nichols, et al., 1998, Owen and Larson, 1991), or at least similar (Liu, et al., 2000, Schingoethe, et al., 1999), milk production compared to soybean meal in dairy rations. Also, wet or dried distillers grains with solubles can be efficiently utilized in finishing diets of ruminants as a protein and energy source (Larson, et al., 1993, Lodge, et al., 1997a, Lodge, et al., 1997b).

Most of the DDGS research involving dairy cattle has been conducted in temperate climates. The objectives of this feeding trail were to 1) to compare the feeding value of DDGS with corn, SBM and roasted soybeans in lactating dairy cow rations and test the feasibility of DDGS in the dairy rations in a hot and humid sub-tropical environment, and 2) to test the DDGS stability under hot and humid storage conditions.

Material and Methods

Cows and Diets

The trial was conducted on Lin-Fong-Ying Dairy, a commercial dairy farm located in Tainan County, Taiwan. The location of LFY Dairy is about 20Km south of the Tropic of Cancer. The dairy herd consists of a total 600 cattle, including 290 milking cows. The main barn of this dairy is a typical free-stall facility with an exercise lot for each pen. The barn is equipped with a sprinkler and misting system for evaporative cooling during the hot season. A double 12 milking parlor with automatic take-off's is operated by 4 milkers.

Fifty primparous Holstein cows were randomly assigned to the Control and DDGS treatment groups based on their Days In Milk (DIM), pre-treatment milk production, and body condition score (BCS). The average DIM of two groups was the same (149 ± 56 d). The average milk production of the Control and DDGS group at grouping was 22.3 ± 2.8 kg and 22.4 ± 3.7 kg, respectively. The average BCS of the Control and DDGS group at grouping was 3.0± 0.3 kg and 3.1 ± 0.3 kg, respectively. The feeding trial consisted of a two-week of adjustment period to allow the cows to adapt to the pen, followed by an eight-week experimental period for data collection.

The DDGS was imported from Glacial Lakes Energy LLC (Watertown, SD) in a 40 feet container, and was re-packaged in 50 kg feed bags with a plastic lining. DDGS bags were stored in a covered steel pole barn for ten weeks. A random sample of DDGS was obtained weekly from storage at the Lin-Fong-Ying Dairy and analyzed for moisture (dry matter), mycotoxins (aflatoxin, ochratoxin, T-2 toxin, citrinin, fumonisin, and zearalenone) by HPLC, and measures of oxidative rancidity of fat (peroxide value and free fatty acids).

Two adjacent pens in the main free-stall barn were used to hold the two groups of lactating dairy cows. There were 25 headlocks in each pen. At the end of first 4 weeks of the experimental period, two groups were switched to the opposite pen in order to minimize the influence of the pen location, and to account for the pen effects if they existed A computerized temperature and humidity recording system (Watchdog® 450) was installed in the middle of two pens to record hourly temperature (T, ?) and relative humidity (RH, %) during the entire experimental period. Temperature Humidity Index (THI) was calculated as follows (Hahn, 1999) :

$$THI = 0.81 \times T + RH\ (T-14.4) + 46.4$$

Cows were fed a total mixed ration (TMR) containing either 0% (Control) or 10% (DDGS) DM from DDGS. DDGS partially replaced some of the soybean meal, corn, steam-flaked corn and roasted soybeans in the TMR ration (Table 1). The rations were formulated using Cornell Net Carbohydrate and Protein System (CNCPS, v 4.26) (Barry, et al., 1994) to meet the requirement of metabolizable protein (MP), metabolizable energy (ME), calcium, and phosphorus. Both rations were formulated to be iso-nitrogenous. The dry matter content of corn silage was measured daily using a microwave to determine the amount of "as-fed" corn silage to add to the TMR for both groups. The rations were fed ad libitum twice daily. The amount of ration offered to each group was adjusted as needed to limit the amount of orts to be no more than 5 to 10 % of the total amount of feed offered. Orts were collected and weighed before each feeding. Samples of rations and orts were collected from each feeding and the dry matter content of these samples was determined. The average daily DMI of each group was calculated accordingly. Weekly composite samples of the ration and orts were analyzed for DM using a microwave and drying at 65^{O}C for 48 h. After the trial was completed, all the ration and orts samples were sent to the Dairyone® Forage Lab (Ithaca, NY) in the US for chemical analysis. All the samples were analyzed for crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), fat, non-fibrous carbohydrate (NFC), lignin, ash, soluble protein (SP), net energy (NE), Ca, P, Mg, K, and S. One composite DDGS sample was analyzed for CP, SP, acid detergent insoluble crude protein(ADICP), neutral detergent insoluble crude protein (NDICP), NDF, ADF, fat, lignin, ash, starch, sugar, NFC, non-starch carbohydrate (NSC), total digestible nutrients (TDN), NE, Ca, P, Mg, K , Na, Fe, Zn, Cu, Mn, Cl, S, *in vitro* true digestibility (IVTD), and *in vitro* NDF digestibility (NDFD). The body condition score (BCS, 1 – 5 scale) of all animals was evaluated by the same technician every 4 weeks during the experimental period.

Cows were milked twice daily at 0500 and 1700h throughout the experiment. The DHI test was conducted every two weeks. The a.m. and p.m. milk samples were combined and were analyzed for crude protein, fat, lactose, solid-non-fat (SNF), milk urea nitrogen (MUN), and somatic cell count (SCC) by the laboratory at Taiwan Livestock Research Institute (Hsin-Chu). To accommodate the management of the dairy farm, cows with clinical mastitis were moved to a hospital pen and were not allowed to re-enter the experiment.

Statistical Analysis

Average nutrient analysis of Control and DDGS TMR rations were compared using one-way ANOVA of SPSS (SPSS, 1999). DMI, milk production, milk

components, and BCS were analyzed as a completely randomized design by ANOVA using general linear models procedure of SPSS (SPSS, 1999) to account for effects of treatment, pen and the interaction between treatment and pen. For analysis of milk production data, pre-treatment milk production level was used as a covariate. Differences between experimental groups were considered to be significant at $P < .05$ unless otherwise noted.

Table 1. Composition and Nutrient content of Control and DDGS Rations.

INGREDIENT	*CONTROL % OF DM*	*EXPERIMENTAL(DDGS) % OF DM*
Corn silage	22	22
Alfalfa hay	19	19
Bermuda hay	5	5
Soybean hulls	11	11
Corn grain, ground	18.4	12.8
Steam-flaked corn	6	4
Soybean meal, 44%	6	4.8
Roasted soybean	2	1
Fish meal	0.5	0.5
Corn gluten feed	3.2	3.2
DDGS	0	10
Molasses	1.6	1.6
Dicalcium phosphate	0.48	0.08
Limestone	0.64	0.88
Salt	0.56	0.56
Bypass fat	2	2
Vitamin/Mineral mix	0.08	0.08
Sodium bicarbonate	1.5	1.5
Estimated composition of the TMR[1]		
Expected DMI, kg/day	18.4	18.4
CP, % of DM	15.7	15.7
DIP, % of CP	62	57
NDF, % of DM	35	38
NFC, % of DM	39	36
Fat, % of DM	4.9	5.7
Ca, % of DM	0.87	.88
P, % of DM	0.43	.44

[1]Estimated by Cornell Net Carbohydrate and Protein System.

Results and Discussion

As shown in Table 2, the chemical analysis of the DDGS pooled sample is summarized. The CP content of this sample was 32.8% (DM basis), which was higher than the Dairy NRC (2001) "book" value of 29.7% (NRC, 2001). ADICP, which may be indigestible by the animal, was only 1.1% of DM (3.4% of CP). In Dairy NRC (2001), ADICP of DDGS was 5% of DM. A low ADICP value indicates that the DDGS source used in this study was not over-heated in the drying process. Most of the starch in the corn grain is fermented into ethanol and the residual starch and sugar content of this pooled DDGS sample were 5.6% and 5.2% of DM, respectively. The relatively high crude fat (13.0% of DM) and phosphorus (0.93% of DM) content are valuable nutritional characteristics of DDGS. The high crude fat value resulted in a high TDN (101%) value for the DDGS used in this trial. Therefore, the estimated NEL-3X of this DDGS was 2.49 Mcal/ kg DM. Compared with the NEL-3X values of DDGS (1.97 Mcal/kg) and ground corn grain (2.01 Mcal/kg) listed in the Dairy NRC (2001), the DDGS used in this trial contained a much higher energy value and was expected to support a higher level of milk production.

Table 2. Chemical Analysis of DDGS Pooled Sample. (%, DM Basis)

Nutrient	Concentration	Nutrient	Concentration
DM, %	87.1	Mg, %	0.37
CP, %	32.8	K, %	1.11
ADICP, %	1.1	Na, %	0.18
NDICP, %	10.3	Cl, %	0.15
ADF, %	11.5	S, %	0.49
NDF, %	32.0	Fe, ppm	87
Lignin, %	5.8	Zn, ppm	55
NFC, %	26.6	Cu, ppm	4
NSC, %	10.8	Mn, ppm	17
Starch, %	5.6	Mo, ppm	1.0
Sugar, %	5.2	TDN, %	101
Crude fat, %	13.0	NEL, Mcal/kg	2.49
Ash, %	5.82	NEM, Mcal/kg	2.68
Ca, %	0.05	NEG, Mcal/kg	1.91
P, %	0.93		

As shown in Figure 1, DDGS used in this trial was highly digestible when evaluated by an *in vitro* ruminal fermentation procedure. During the first 6 h of

fermentation, 71% of DDGS was degraded. Most of the degradable fraction (90%) was digested by 30 h of fermentation. The fiber fraction (NDF) of DDGS was highly digestible. After 48 h of *in vitro* fermentation with rumen fluid, 69% of the NDF of DDGS was digested. This result agreed with the data published by Chen et.al. (1999) and Schingoethe et.al. (1999).

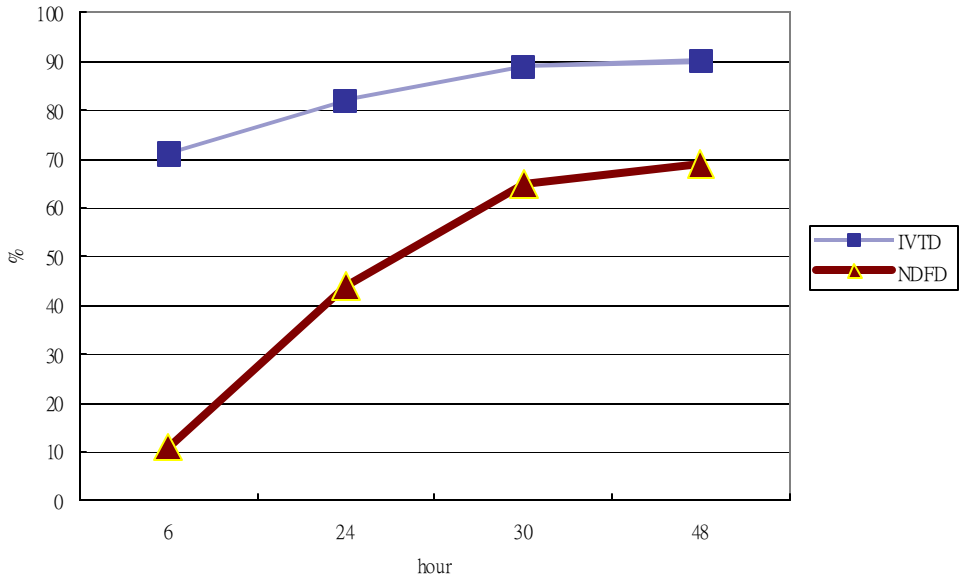

Figure 1. *In Vitro* True Digestibility (IVTD) and Neutral Detergent Fiber Digestibility (NDFD) of the DDGS pooled sample.

The average nutrient level of weekly composite rations was determined and compared between Control and DDGS treatment group (Table 3). The difficulty of TMR sampling and sub-sampling of the weekly composite sample contributed to some of the variation in nutrient content in these comparisons. The group fed the DDGS ration had significantly higher crude fat content in their diet than the ration fed to the Control group ($P < .05$). However, the addition of 10% DDGS provided significantly more lignin ($P < .10$), less Ca ($P < .10$) and less NFC ($P < .05$) to the ration of DDGS group than the Control ration. There were no significant differences in CP, ADICP, ADF, NDF, NEL, P, Mg, K, Na, S, and ash. These results were consistent with the nutritional characteristics of DDGS.

The average daily dry matter intake (DMI) of the Control and DDGS groups were 17.8 ± 1.2 and 17.6 ±1.0 kg, respectively. The addition of DDGS did not influence the DMI of the experimental animals and there was no pen effect on DMI (Table 4), but the actual DMI was lower than the DMI prediction by CNCPS. This

DMI discrepancy might result from the heat-stressed conditions experienced during the trial. Although the trial was conducted from September to November, the cows were still under heat-stressed environment (THI > 72) (Figure 2).

Table 3. Average Nutrient Analysis of Weekly Composite Rations Fed to the Control and DDGS Groups.

Nutrient	Control	DDGS	SE	*P* -value
Crude protein, %	14.0	14.4	0.38	0.29
ADICP, %	0.67	0.69	0.09	0.81
ADF,%	26.5	28.0	1.06	0.19
NDF, %	41.2	42.5	0.94	0.18
Crude Fat, %	4.5	5.3	0.30	0.02
NEL, Mcal/kg	1.60	1.60	0.02	0.89
NFC, %	32.8	30.2	0.82	0.01
Lignin, %	4.3	5.1	0.40	0.07
Ash, %	7.6	7.6	0.19	0.97
Ca, %	0.83	0.77	0.04	0.09
P, %	0.32	0.33	0.02	0.78
Mg, %	0.25	0.24	0.02	0.70
K, %	1.46	1.38	0.07	0.22
Na, %	0.65	0.65	0.04	0.83
S, %	0.21	0.23	0.01	0.11

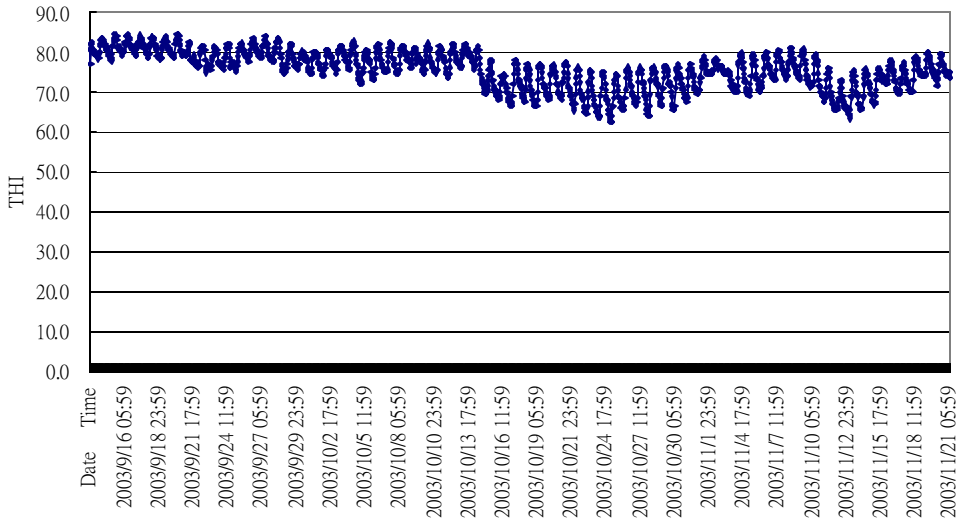

Figure 2. Temperature-Humidity-Index (THI) during the trial.

The average milk production of all cows in Control and DDGS groups on each DHI day were are shown in Figure 3. Cows in the DDGS group tended to have a higher average milk production than cows in the Control group. There was no difference in milk production before ration treatment (2003/9/6 and 2003/9/21 DHI). After the feeding of experimental rations, the cows in the DDGS group produced more milk than the cows in the Control group on each DHI test day. The increase in milk production of cows fed the DDGS ration may have been due to the high feeding value of DDGS or lower DIM of DDGS group. It is unlikely that this difference was due to a pen effect because there was no difference in milk production between two groups during the adapting (pre-treatment) period. The removal of mastitis cows from the trial resulted in a difference of DIM between two groups, but this difference was small (6 days). DDGS, therefore, may have a real advantage for supporting higher milk production of mid-lactating cows under heat-stressed conditions. Both groups showed a significant drop in milk production in the last DHI test. The THI increased during this period of time (Figure 2) and feeding poor corn silage quality obtained from a new silage bag were two possible reasons to explain this phenomenon.

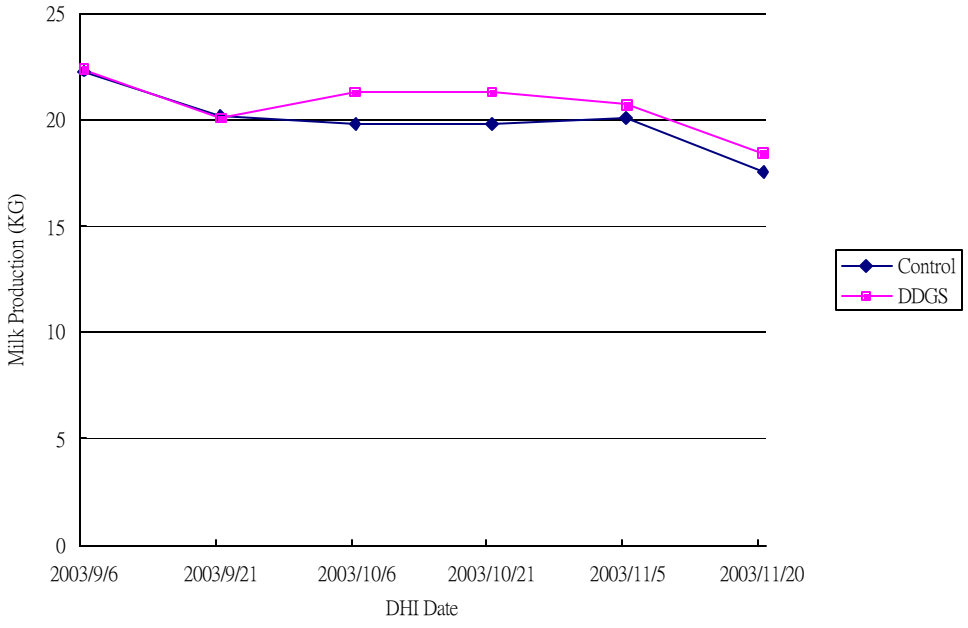

Figure 3. Average Milk Production of Cows fed the Control and DDGS TMR.

The DHI data from the animals that completed the trial were used for statistical analysis (Table 4). Using pre-treatment milk production level as a covariate, cows in the DDGS group produced significantly higher (0.9 kg/d/h) milk than the Control group ($P < .05$). The DDGS provided more fat to the ration fed to the DDGS group,

and could be a primary factor for supporting higher milk production. However, DDGS is highly digestible (Figure 1) and may contain some unidentified compounds that enhance rumen function and animal performance. There was no pen effect on milk production. However, the treatment and pen interaction was significant (P= .003). Although milk fat percentage was not different between treatments or pens, cows in the DDGS group tended to produce more milk fat per day than cows in the Control group (P= .10). The higher milk fat production can be attributed to the higher level of milk production of cows in the DDGS group. Although the addition of 10% DDGS in the ration significantly decreased the milk protein percentage (P= .001), the amount of milk protein produced per day was not affected. One of the concerns regarding the use of DDGS in the lactating dairy cow rations is its high fat content, which may interfere with ruminal fermentation and may decrease microbial protein production and milk protein. However, the higher level of milk production of cows in the DDGS group compensated for the negative effects of feeding DDGS on milk protein percentage. Both treatment (P= .07) and pen (P= .004) effects were statistically significant for lactose percentage in milk. It is not clear why these responses were observed. The BCS was not significantly different between dietary treatments during the trial.

Table 4. Effects of Feeding TMR with and without 10% DDGS on the Milk Production, Milk Composition and BCS of Mid-Lactating Cows under Heat-stressed Conditions.

Response variable	Treatment (T)		Pen (P)		SE	*P*- value		
	Control	DDGS	1	2		T	P	T×P
DMI, kg/d	17.8	17.6	17.8	17.6	0.20	0.32	0.29	0.012
Milk, kg/d	19.5	20.4	19.8	20.1	0.44	0.04	0.46	0.003
Fat, %	4.51	4.45	4.43	4.53	0.13	0.61	0.41	0.69
Fat, kg/d	0.86	0.91	0.87	0.91	0.03	0.10	0.22	0.07
Protein, %	3.45	3.32	3.41	3.37	0.04	0.001	0.17	0.73
Protein, kg/d	0.66	0.68	0.67	0.67	0.02	0.40	0.97	0.02
Lactose, %	4.85	4.90	4.92	4.83	0.03	0.07	0.004	0.84
Total Solid, %	13.5	13.4	13.5	13.4	0.16	0.36	0.77	0.63
MUN, mg/dL	11.2	11.8	12.3	12.8	0.50	0.23	0.80	0.04
SCC, 10^4/ml	26.9	35.4	35.9	26.4	13.8	0.54	0.49	0.76
BCS	2.96	3.01				0.21		

Summary

DDGS is a good source of protein, fat, phosphorus, and energy for lactating dairy cows. Good quality DDGS is highly digestible in the rumen and can improve animal performance. Using good quality DDGS at a level of 10% of the ration will partially replace corn grain, soybean meal and roasted soybeans and increase the fat content and decrease the NFC content. The addition of 10% DDGS improved the average milk production level of mid-lactating dairy cows by 0.9 kg per cow per day. The percentage of milk protein was decreased, but the amount of milk protein produced per cow per day was not affected by feeding the TMR containing DDGS. These results suggest that DDGS can be effectively used in a TMR by mid-lactating dairy cows under heat-stressed climatic conditions, and is a potential high quality co-product for the dairy industry in sub-tropical and tropical regions of the world.

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