Study Report

Effects of Corn Distillers Dried Grains with Solubles (DDGS) Under Hot Summer Conditions in Lactating Dairy Cows

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I. Objectives

Corn distillers dried grains with solubles (DDGS), once considered a by-product of fuel ethanol production, are a recognized feedstuff for livestock animals. Today, DDGS is attracting increasing attention and is manufactured under quality-controlled conditions as a main product for livestock feed. DDGS is also expected to be beneficial to the livestock industry, because recent research projects have revealed that it contains high levels of protein and fermentation products.

In Japan, DDGS has been used to a limited extent, but its use is increasing dramatically. For example, the import of DDGS in 2008 has nearly doubled since the previous year. However, only a limited amount of information has been obtained about the properties of DDGS from feeding trials. In lactating dairy cows, in particular, the effect of DDGS on the physical condition and properties of raw milk is poorly understood, hindering its full potential as a feedstuff in dairy cattle. Against such backgrounds, this trial aimed to add a set of key information on the use of DDGS in dairy cattle under high temperature conditions. To this end, a total mixed ration (TMR) supplemented with DDGS was fed to lactating dairy cows during the hot summer months, and its effect on dry matter (DM) intake (the indicator of palatability), blood parameters, milk yield and fatty acid composition in raw milk was assessed.

II. Materials and Methods

1. Study Site

A dairy research farm at the National Agricultural Research Center for the Kyushu Okinawa Region (Koshi-city, Kumamoto)

2. Investigator

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3. Study Period

From July 1, 2008 to August 27, 2008

(DDGS feeding period: From July 14, 2008 to August 13, 2008)

4. Study Animals

Each of the test (DDGS) and control groups contained three Holstein cows. The mean age, parity and number of days after the last calving were, respectively, 4.3±1.6, 2.3±1.2 and 128±19.1 in the DDGS group and 4.2±1.5, 1.7±0.6 and 117.3±38.2 in the control group.

5. Feed

1) DDGS

Dakota Gold® (Poet Nutrition, Sioux Falls, SD, USA) was used. Table 1 shows the feed composition provided by the Poet Nutrition.

Table 1. Feed composition of DDGS (Dakota Gold®)

DM (%)	90.3
CP (%)	29.8
Crude fat (%)	11.5
Crude fiber (%)	6.9
ADF (%)	9.0
NDF (%)	26.5
Ash (%)	5.0

DM: dry matter, CP: crude protein, ADF: acid detergent fiber, NDF: neutral detergent fiber

(Excerpt from www.dakotagold.com)

2) Basal diet

Before and after the DDGS feeding period, cows received *ad libitum* a TMR that was prepared at the study site primarily from corn silage, Italian rye grass silage, steam-rolled corn, and defatted soybean-meal flakes [total digestible nutrient (TDN), 70.0%; crude protein (CP), 13.7%; neutral detergent fiber (NDF), 35.0%; and acid detergent fiber (ADF), 21.0%].

3) Test feed (DDGS-containing feed)

The test feed was prepared so that its TDN and CP contents were equivalent to those of the basal diet as shown in Table 2. Mineral salt was offered *ad libitum*.

Table 2. Feed composition of test feed

	DM basis (%)	
	DDGS group	Control group
Corn silage	35.0	35.0
Italian rye grass silage	17.0	17.0
DDGS	20.0	—
Steam-rolled corn	18.0	20.0
Defatted soybean meal	5.0	18.0
Compounding ingredient	3.0	8.5
DM	49.0	48.9
TDN	72.2	72.3
CP	14.4	14.5
NDF	37.0	34.0
ADF	20.0	19.9

6. Study Design

All animals were kept under the same conditions throughout the study period. Figure 1 shows the treatment and sampling schedule in this trial.

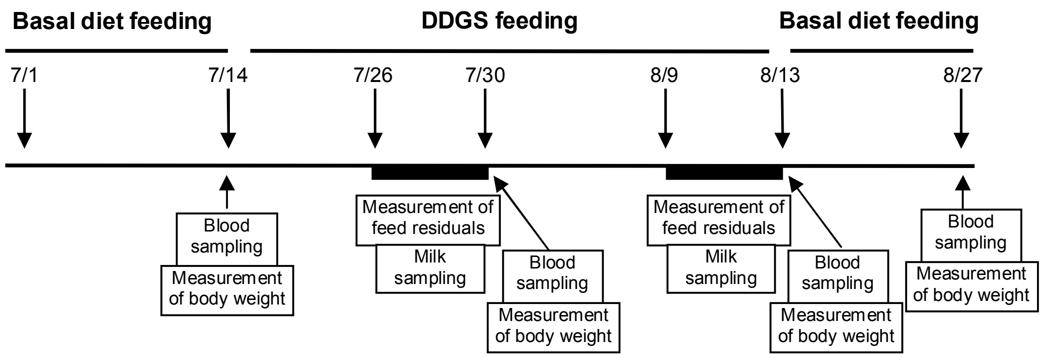


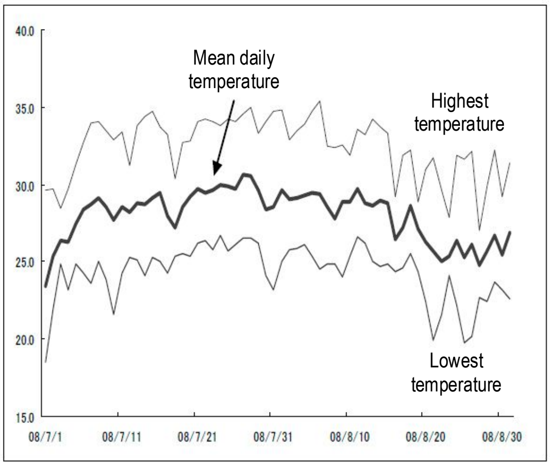
Figure 1. Overview of the DDGS feeding trial

7. Animal Management

1) Cow barn

Between July 1 and 13 and between August 15 and 27, the cows were tethered to a stall in the daytime. To control temperature in the barn, misting and fanning were conducted, and water was sprinkled over the roof. The cows were released to the paddock at night.

Between July 13 and August 14, the cows were tethered the whole day in a stanchion barn with a slate roof. To control temperature, misting and fanning were performed, and water was sprinkled over the roof in the daytime. At nighttime, only the fan was kept on. Figure 2 and Table 3 show the ambient temperature and humidity in the barn. Milking was conducted twice a day at 8:30 and 18:00.



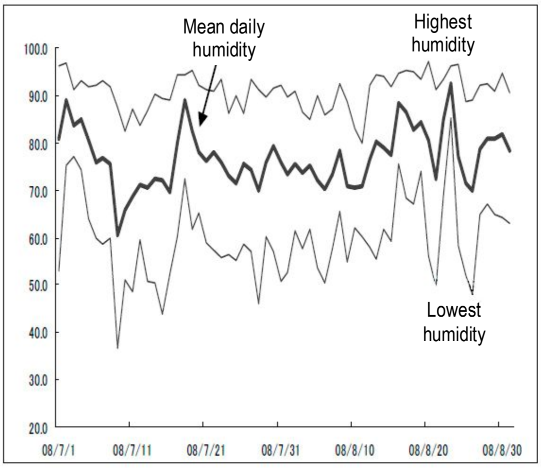


Figure 2. Changes in the ambient temperature and humidity in the barn during the study period

Table 3. The ambient temperature (˚C) and humidity (%) during the study period

	Mean daily temperature	Mean daily humidity	Highest temperature	Lowest temperature	Highest humidity	Lowest humidity
Pre-DDGS period (July 1-13)	27.5	75.7	31.9	23.6	90.3	59.1
Feeding period (July 14-August 13)	29.1	75.1	33.7	25.4	89.9	57.1
Post-DDGS period (August 14-27)	26.5	80.4	30.8	23.0	93.2	63.8

2) Feeding

Between July 1 and 13 and between August 15 and 27, basal diet was given *ad libitum* at 9:00 and 18:00. Between July 13 and August 14, the test diet was given *ad libitum* at 9:00, 15:00 and 18:00 in the test group, while control animals were kept on the basal diet.

3) Water

Purified tap water was given *ad libitum* via commercial cup waterers.

8. Parameters and Analysis

1) Diet composition

DDGS was analyzed for the DM ratio, crude ash content and crude fat content by the established methods.

2) Ambient temperature/humidity in the barn and rectal temperature

Ambient temperature and humidity in the barn were measured automatically every 30 minutes by a data logger throughout the study period. The rectal temperature of each cow was measured every morning immediately after milking using a rectal thermometer for animals.

3) Feed intake

From Day 13 to Day 17 and from Day 27 to Day 31 of the DDGS feeding period, TMR and DM intakes between 9:00 and 8:30 (next day) were measured.

4) Body weight

The body weight of each cow was measured after morning milking, immediately before the first DDGS feeding, and on Days 17 and 31 of the DDGS feeding period and on Day 14 of the post-DDGS period.

5) Milk yield and nutritional composition of raw milk

Milk yield was measured with a milk meter at every milking time (morning and evening) throughout the study period. The nutritional composition of raw milk (1-day yield) was determined immediately before the first DDGS feeding, on Days 17 and 31 of the DDGS feeding period, and on Day 14 of the post-DDGS period. The parameters were fat content, protein content, lactose content, milk urea nitrogen (MUN) level, and somatic cell count. Fatty acid composition was analyzed in the raw milk of both groups collected on Day 30 of the feeding period.

6) Blood samples

Blood samples were collected via the juglar vein prior to morning milking, just before the first DDGS feeding, on Days 17 and 31 of the DDGS feeding period, and on Day 14 of the post-DDGS feeding period. Hematological parameters (RBC, WBC, hemoglobin and hematocrit) were immediately measured after sampling. After plasma separation, the following biochemical parameters were measured: total protein; albumin; sulfhydryl (SH) groups; thiobarbituric acid reactive substances (TBARS); vitamin C; gamma-glutamyl transpeptidase (GGT) activity; glutamic-oxaloacetic transaminase (GOT) activity; glucose (GLU); blood urea nitrogen (BUN); calcium (Ca); and phosphorus (P).

9. Statistical Analysis

All the measured values were compared between the DDGS group and the control group, and among the different time points by Student's *t*-test ($P < 0.05$).

III. Results and Discussion

1. Body weight and rectal temperature

There was no significant difference in body weight between the DDGS group and the control group either before or after the commencement of DDGS feeding. In both groups, the body weight did not significantly change throughout the study period, although slight variations were noted (Table 4).

Table 4. Body weight changes

	DDGS group (n =3)	Control group (n=3)
Pre-DDGS feeding	622.8±116.6	621.0±99.6
Day 17 on DDGS diet	618.8±101.4	614.6±97.2
Day 31 on DDGS diet	635.0±102.9	622.1±100.9
Day 14 post-DDGS	643.5±128.7	632.8±101.1

Throughout the study period, the daily mean ambient temperature was above 23°C, the lowest temperature known to affect milk yield. It was 29.1°C during the DDGS feeding period. Due to the hot conditions, the rectal temperatures of the cows in both groups were above the normal range of 38.3-38.5°C (Table 5). The DDGS group showed lower rectal temperatures than those of the control group, although the difference was not statistically significant. Thus, the body weight and rectal temperature of lactating dairy cows were not affected under the hot conditions by approximately 1-month feeding of TMR that contained DDGS at 20% on a DM basis.

Table 5 Rectal temperature changes

	DDGS group (n = 3)	Control group (n = 3)
Pre-DDGS feeding (July 1-13)	39.0±0.44	39.2±0.52
Day 1-17 on DDGS diet	38.8±0.36	39.2±0.56
Day 18-31 on DDGS diet	38.8±0.38	39.1±0.56
Post-DDGS feeding (August 14-27)	38.6±0.50	39.0±0.53

2. Feed intake

By compositional analysis of the DDGS used in this trial, the DM ratio, crude fat and ash contents were 90.0%, 10.8%, and 5.0%, respectively (DM basis). These values are similar to the analytical data provided by the manufacturer (Table 1).

Table 6 shows the DM intake in both groups during the DDGS feeding period. There was no significant difference between the two groups. These results suggest that the presence of DDGS has no influence on the palatability.

Table 6. The effect of DDGS in TMR on DM intake (kg/day)

	Day 13-17	Day 27-31
DDGS group (n = 3)	23.5±2.2	23.7±2.3
Control group (n = 3)	22.2±1.9	21.9±3.2

3. Blood analysis

The DDGS group showed higher WBC counts than those of the control group before and after the commencement of DDGS feeding, although the difference was not significant. In the DDGS group, an increase in the WBC count was seen on Day 31 of the feeding period, but it was not significantly different from the pre-DDGS feeding value. In the control group, RBC counts during and after DDGS feeding were significantly higher than that before DDGS feeding, but these variations were inconsistent. Throughout the study period, there was no significant difference in RBC counts between the two groups. The hemoglobin level in the DDGS group was high during the study period, and the difference from the control group was significant on Day 17 of the DDGS feeding period. In both groups, hemoglobin levels showed a tendency to increase over time. The hematocrit did not significantly change during the study period in either group (Table 7). Based on these results, the blood cell counts, hemoglobin and hematocrit of lactating dairy cows were not significantly affected by DDGS under the high temperature conditions.

Table 7. The effect of DDGS feeding on hematological parameters

	WBC count ($\times 10^2$ cells/mL)	RBC count ($\times 10^4$ cells/mL)	Hemoglobin (g/dL)	Hematocrit (%)
Pre-DDGS feeding				
DDGS group	108.3±25.7	550.7±75.3	8.5±0.1	25.9±1.2
Control group	94.3±35.7	518.7±25.0	8.1±0.6	24.5±1.7
Day 17 on DDGS diet				
DDGS group	107.3±28.2	560.3±67.6	8.8±0.2	26.3±0.9
Control group	89.0±28.5	540.7±36.2	8.1±0.5[#]	25.0±2.2
Day 31 on DDGS diet				
DDGS group	146.0±36.4	585.7±52.3	9.2±0.2	27.6±0.1
Control group	84.7±39.9	553.7±63.4	8.3±1.1	25.2±3.7
Day 14 post-DDGS				
DDGS group	120.0±45.1	587.0±61.7	9.1±0.4[*]	27.9±1.3
Control group	96.7±37.8	600.3±42.1[*]	8.8±1.0	27.4±0.4

[*] With a significant difference from the pre-DDGS value (P<0.05)
[#] With a significant difference between the two groups (P<0.05)

The GGT activity in the control group was significantly higher than that in the DDGS group before DDGS feeding and was continuously high over the study period. The GOT activity in the DDGS group was significantly higher than that in the control group before DDGS feeding and was continuously high over the study period. However, these values were not considerably beyond the standard ranges. It remains to be determined whether DDGS feeding is associated with these findings (Table 8). The plasma GLU level did not dramatically change, although its difference between the two groups increased over time from 1.3 mg/dL (pre-DDGS) to 2.0 mg/dL (Day 17 on DDGS diet), 6.7 mg/dL (Day 31 on DDGS diet) and 5.6 mg/dL (post-DDS). This tendency seemed to arise from different nutritional conditions of dairy cows between the two groups. The BUN level was not significantly different between the two groups, except on Day 17 of the DDGS feeding period when it was significantly higher in the DDGS group than that in the control group. In both groups, the calcium level decreased and the phosphorus level increased over the study period. However, neither of the parameters showed a significant intergroup difference (Table 8). Together, DDGS feeding did not result in a statistically significant difference in any parameter shown in Table 8 during DDGS feeding.

Table 8. The effect of DDGS feeding on plasma components (1)

	GGT (u/L)	GOT (u/L)	GLU (mg/dl)	BUN (mg/L)	Ca (mg/dl)	P (mg/dM)
Pre-DDGS feeding						
DDGS group	34.3±5.9	72.3±12.1	69.7±7.5	12.2±3.9	12.7±0.6	3.9±1.7
Control group	46.7±0.6#	59.0±6.2#	68.3±1.5	9.6±1.0	12.5±0.5	3.8±0.3
Day 17 on DDGS diet						
DDGS group	37.0±5.2	78.3±15.3	70.3±5.1	10.9±0.9	12.4±0.4	5.0±1.8
Control group	47.0±1.7#	57.3±2.3#	68.3±2.9	8.8±0.2#	12.3±0.4	4.7±1.2
Day 31 on DDGS diet						
DDGS group	38.3±7.8	75.3±21.4	76.7±8.6	10.8±1.7	12.3±0.8	4.8±1.1
Control group	43.7±6.1	60.7±4.0	70.0±4.0	9.7±0.9	11.5±0.9*	4.6±0.7
Day 14 post-DDGS						
DDGS group	32.7±2.5	73.5±13.1	68.3±2.5	8.0±1.6*	11.5±0.3*	4.7±0.4
Control group	45.3±2.5#	60.7±4.9	62.7±3.8#	9.1±0.7	11.7±0.4*	5.1±1.6

* With a significant difference from the pre-DDGS feeding value (P<0.05)
\# With a significant difference between the two groups (P<0.05)

The plasma total protein level significantly increased after the commencement of DDGS feeding in both groups (Table 9). The albumin level was not significantly different between the two groups before DDGS feeding. However, the albumin level in the DDGS group significantly increased after the commencement of DDGS feeding with statistical significances compared to the pre-DDGS value and to those of the control group.

Table 9. The effects of DDGS feeding on plasma component (2)

	Total Protein (mg/mL)	Albumin (mg/mL)	SH groups (mM)	Vitamin C (mg/L)	TBARS (nM)
Pre-DDGS feeding					
DDGS group	80.6±3.1	29.8±0.4	411.2±9.7	5.0±1.5	60.7±10.9
Control group	81.1±2.7	29.6±1.3	409.2±22.0	4.5±1.4	50.9±8.1
Day 17 on DDGS diet					
DDGS group	85.2±3.9	32.5±1.4*	446.8±19.8*	4.9±1.2	57.2±6.2
Control group	84.6±0.5*	29.6±3.8	427.7±31.6	4.5±1.0	72.6±8.5#
Day 31 on DDGS diet					
DDGS group	88.3±4.3*	33.9±2.5*	454.8±27.2*	4.6±1.9	68.3±15.8
Control group	84.1±0.9*	32.3±1.4	429.7±26.2	4.3±0.5	58.8±21.4
Day 14 post-DDGS					
DDGS group	86.6±13.6	33.9±1.0*	431.4±10.8*	5.2±1.1	61.2±3.6
Control group	85.3±1.8*	33.5±3.3	450.4±34.9*	5.3±1.0	51.1±11.8

* With a significant difference from the pre-DDGS feeding value (P<0.05)
\# With a significant difference between the two groups (P<0.05)

Similarly, the level of SH groups in the DDGS group (a reductant component in plasma) was higher during DDGS feeding than that before DDGS feeding. The Vitamin-C levels did not significantly change over time and were not significantly different between the two groups. The TBARS level, an indicator of lipid peroxide, showed some but inconsistent variations throughout the study period in both groups.

Thus, the plasma levels of protein, albumin and SH groups in the DDGS group were higher than those in the control group, although they were within the normal ranges. DDGS feeding may have affected the nutritional condition or oxidative stress level in lactating dairy cows. To prove this, further trials are required in dairy cows under experimentally induced poor nutritional conditions or under excessive oxidative stress during the hot summer period.

4. Milk yield and milk composition

There was no difference in milk yield between the two groups during the study period (Table 10). Compared to the pre-DDGS values, however, the DDGS group showed an increased milk yield during and after DDDG feeding, while the control group did not. The percentage milk fat was not significantly different between the two groups. The DDGS group showed lower protein ratios and higher lactose ratios compared with the control group during the DDGS feeding period. Statistically significant intergroup or over-time differences were not seen in somatic cell count because of considerable individual variations. MUN levels over time were similar to those of BUN, with less individual variations. In the DDGS group, MUN decreased significantly after the commencement of DDGS feeding, and it was still low on Day 14 of the post-DDGS feeding period. However, there was no significant difference between the two groups during the study period.

Table 10. The effect of DDGS feeding on lactation performance (1)

	Milk yield[1] (kg/day)	Fat (%)	Protein (%)	Lactose (%)	Somatic cell count (× 10^4 cells/mL)	MUN (mg/L)
Pre-DDGS feeding						
DDGS group	35.4±7.7	3.2±0.3	2.7±0.0	4.6±0.1	11.5±16.1	14.2±1.3
Control group	33.3±4.7	3.5±0.7	2.9±0.1#	4.6±0.1	8.5±4.6	13.1±0.7
Day 17 on DDGS diet						
DDGS group	39.2±7.6	3.3±0.2	2.8±0.1	4.7±0.1	15.9±20.9	12.2±0.6*
Control group	33.2±4.5	3.6±0.6	3.1±0.2#	4.5±0.1#	17.8±12.2	13.1±1.3
Day 31 on DDGS diet						
DDGS group	37.8±6.3	3.5±0.3	2.8±0.1	4.7±0.1	16.2±18.5	11.8±0.8*
Control group	31.5±4.5	3.8±0.6	3.2±0.2#	4.5±0.1#	13.4±7.1	12.4±1.0
Day 14 post-DDGS						
DDGS group	36.5±6.0	3.3±0.4	3.0±0.0*	4.7±0.1	18.5±25.5	9.2±0.9*
Control group	31.6±3.7	3.2±0.2	3.0±0.1	4.5±0.1#	9.5±8.3	10.3±0.8*

[1] Values are mean ± standard deviation for the preceding 5 days.
* With a significant difference from the pre-DDGS feeding value ($P<0.05$)
\# With a significant difference between the two groups ($P<0.05$)

Table 11. The effect of DDGS feeding on lactation performance (2)

	Fat (kg/day)	Protein (kg/day)	Lactose (kg/day)
Pre- feeding			
DDGS group	1.20±0.24	1.03±0.26	1.73±0.45
Control group	1.21±0.12	1.03±0.18	1.60±0.28
Day 17 of the feeding period			
DDGS group	1.35±0.25	1.12±0.19	1.90±0.38
Control group	1.19±0.12	1.02±0.15	1.51±0.30
Day 31 of the feeding period			
DDGS group	1.35±0.34	1.10±0.18	1.80±0.34
Control group	1.15±0.11	0.97±0.11	1.37±0.21#
Day 14 of the post-feeding period			
DDGS group	1.22±0.17	1.13±0.27	1.75±0.45
Control group	1.22±0.08	1.08±0.05	1.51±0.23

\# With a significant difference between the two groups ($P<0.05$)

Table 11 shows the daily yield of each milk composition. There was no significant difference in fat and protein yields between the two groups. In contrast, the DDGS group showed a higher lactose yield than that of the control group on Day 31 of the post-DDGS feeding period.

DDGS contains a high level of fat, more than 10% on a DM basis, which is predominantly polyunsaturated fatty acid [linoleic acid (18:2)]. Feeding a high-fat diet is thought to inhibit the activity of rumen microbes, leading to reduced proteolytic ability and/or a decreased microbial protein. Decreases in the protein level and MUN in the DDGS group are likely resulted from the inhibition of rumen digestion by high-fat feeding (crude fat content: approximately 4.6%). The cause of the low lactate ratio and yield by DDGS feeding has yet to be determined.

5. Fatty acid composition

Table 12 shows the fatty acid composition of DDGS, which is similar to that of corn oil (Standard Tables of Food Composition in Japan, The Resource Council of the Science and Technology Agency). The fatty acid composition of raw milk after a 30-day feeding of the DDGS-containing diet is shown in Table 12 along with that of the control cows. The DDGS group showed lower ratios of C4 to C17 fatty acids and higher ratios of C18 to C20 fatty acids compared to the control group. It is noteworthy that DDGS-fed cows showed a lower palmitic acid ratio and a higher oleic acid ratio compared to control values.

Table 12. The effects of DDGS feeding on the fatty acid composition (%) of raw milk

		DDGS group (n = 3)		Control group (n = 3)		DDGS
		Mean	S.D.	Mean	S.D.	
Butyric acid	4:0	4.37	0.72	3.67	0.55	—
Caproic acid	6:0	2.57	0.40	2.43	0.51	—
Caprylic acid	8:0	1.37	0.15	1.40	0.30	—
Capric acid	10:0	2.73	0.29	3.03	0.55	—
	10:1	0.33	0.06	0.40	0.10	—
Lauric acid	12:0	2.93	0.12	3.57	0.71	—
Myristic acid	14:0	10.50	0.40	11.43	0.74	—
	14:1	0.90	0.35	1.27	0.06	—
	anteiso-15:0	0.47	0.06	0.50	0.00	—
	15:0	0.87	0.06	1.30	0.61	—
	iso-16:0	0.20	0.00	0.25	0.07	—
Palmitinic acid	16:0	24.90	1.39	30.80	4.79	14.8
Palmitoleic acid	16:1	1.03	0.15	1.33	0.23	0.1
	anteiso-17:0	0.40	0.00	0.40	0.00	—
	17:0	0.53	0.06	0.70	0.17	—
	17:1	0.17	0.06	0.27	0.12	—
Stearic acid	18:0	10.93	1.39	8.80	0.82	2.1
Oleic acid	18:1	25.67	1.70	21.20	5.26	27.3
Linolic acid	18:2 (n-6)	3.50	0.53	2.63	1.12	53
Linolenic acid	18:3 (n-3)	0.27	0.06	0.27	0.06	1.5
Arachidic acid	20:0	0.17	0.06	0.10	0.00	0.4
	20:1	0.23	0.06	0.20	0.00	0.3

IV. Conclusions

After approximately 1-month feeding of TMR, which contained US DDGS at 20% on a DM basis, the following key findings were obtained in lactating dairy cows under the hot summer conditions.

1. There was no significant difference in DM intake, body weight and rectal temperature between the pre- and post-DDGS values, or between the DDGS group and the control group.

2. There was no significant difference in the rectal temperature between the DDGS-fed cows and the control cows.

3. There was no remarkable difference in the hematological parameters between the pre- and post-DDGS values in either group.

4. Some plasma components in the DDGS group were significantly different from those of the control group. However, no consistent tendency was observed in any parameter throughout the study period.

5. There was no significant difference in milk yield between the two groups. In the DDGS group, the percentage milk protein was significantly lower, while the percentage lactose was significantly higher than those in the control group. The DDGS-fed cows showed a higher lactose yield than that in the control group.

6. There was no significant difference in fatty acid composition of raw milk between the two groups. In the DDGS group, however, palmitic acid was lower and linoleic acid was higher than those in the control group. These results seemed to reflect the fatty acid composition of DDGS.

7. In conclusion, when lactating dairy cows were fed a concentrate diet that contained DDGS at 20% on a DM basis (approximately 50% of concentrated feed), there were only marginally negative impacts, if at all, on milk yield and composition, and the cow's conditions were unaffected. Therefore, if it is cost-effective, DDGS (Dakota Gold®) is a possible option as a feedstuff in dairy cows and can be given up to 20% on a DM basis (more than 40% of concentrated feed).

V. Acknowledgements

I would like to thank the staff in the Japan office of the U.S. Grains Council for providing me with the opportunity to conduct this dairy cattle feeding trial of American DDGS, which is new to Japan. I am also grateful to Nosan Corporation for supplying DDGS.