Report of the Results of a DDGS Feeding Trial in Broilers

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I. Objectives

Japan has been importing DDGS (corn distiller's dried grains with solubles) as a new feed ingredient. Being nutritious, DDGS is used mainly in cattle feed and its supply is expected to increase in the future. The quality of products is emphasized in the Japanese livestock industry. Therefore, when a new feed ingredient is used in a compound feed, information on its effects on the quality of the product is important.

In Japan, DDGS has been used in broiler feed for several years. However, in using DDGS for broilers, few information is available on its characteristics as feedstuff or its effects on products from studies that were conducted under the conditions meeting our industry needs in Japan. . In this study, DDGS was fed to a commercial breed of broilers in Japan to assess its effects on the meat production, the quality of the product, such as the amount of peritoneal fat, composition of fatty acids, and meat color, and on the fecal phosphorus concentration.

II. Materials and Methods

1. Study location

Laboratory of Animal Nutrition, Nippon Veterinary and Life Science University (Musashino-shi, Tokyo)

2. Study investigator

Nobuhiro Kimura, Ph.D. in Agriculture, Professor in the Laboratory of Animal Nutrition

3. Housing period

From July 19 to August 20, 2007 (for 32 days)
Acclimatization period: From July 19 to 22, 2007 (for 4 days)
Feeding period: From July 22 to August 19, 2007 (for 28 days)

4. Test animals

Sixty-three 2-week old broiler chicks (Chunky, which holds the largest share [70%] of the domestic market for broiler chickens) were used. They were introduced from a commercial poultry farm on July 19 after being checked to ensure that they were negative for avian influenza.

5. Test diets

<1> DDGS

The DDGS used in this study was produced in Wisconsin in the U.S. and arrived at Yokohama Port in April 2007 by ocean freight. Table 1 shows the analytical values of DDGS obtained at the time of manufacture at the ethanol factory (values provided by the manufacturer).

Table 1 Analytical Values of the DDGS Used in the Study Provided by the Manufacturer (%)

Water	8.11
Dried matter	91.89
Crude protein	29.72
Crude fat	11.95
NFC (non-fiber carbohydrate)	19.88
ADF (acid detergent fiber)	12.94
NDF (neutral detergent fiber)	34.33
Lignin	3.79
Ash	5.37
Calcium	0.09
Phosphorus	1.01
Magnesium	0.41
Sodium	1.62
Sulfur	0.79

<2> Basal diet

A commercial compound feed for fattening broilers, N Mash for Late-stage Broilers (Toyohashi Feed Mills Co., Ltd.), was used as the basal diet. This is a typical compound feed for fattening broilers in Japan. All chicks were fed this diet after introduction. After the start of the study, the animals were provided with this basal diet (control group) or diets containing the basal diet and DDGS.

<3> Test diets

Table 2 Composition of the Test Diets and Their Calculated Metabolizable Energy

	Diet for the control group	Diet for the 10% DDGS group	Diet for the 20% DDGS group	DDGS
Crude protein %	18.0	18.9	19.6	28.3
Crude fat %	6.2	6.7	7.2	10.5
Soluble non-nitrogenous substances %	68.1	66.4	65.0	38.0
Crude fiber %	2.4	2.8	3.2	4.3
Crude ash %	5.3	5.2	5.1	4.4
Calcium %	1.10	1.00	0.93	0.08
Phosphorus %	0.64	0.65	0.64	0.86
Lysine %	1.0	1.0	1.0	-
Metabolizable energy (ME) Mcal/kg	3160	3135	3117	2900

(The values for calcium, lysine, and ME were obtained by calculation. The symbol "-" indicates that measurement was not performed.)

The following 3 different test diets were used: (1) The above-mentioned basal diet (for the control group), (2) a diet containing 9.6% DDGS prepared by adding 10% (outer percentage) DDGS to this basal diet (10% DDGS group), and (3) a diet containing 16.7% DDGS prepared by adding 20% (outer percentage) DDGS to the basal diet (20% DDGS group). In mixing DDGS, lysine alone was added to the diets so that all 3 diets contained 1% lysine.

Table 2 shows the analytical values of the ingredients and the calculated values of metabolizable energy (ME) in the test diets.

6. Grouping

After being weighed and sexed, the 2-week-old broiler chicks were allocated to groups (21 animals per group) so that the mean weight and the numbers of males and females were similar in each group to the extent possible. Table 3 shows the grouping. Sex was determined at a later date. The ratio of males was lower in the 20% DDGS group than in the other groups.

Table 3 Grouping

Group	No. of animals			Acclimatization period	Study period
	Male	Female	Total	For 2 days July 20 to 21, 2007 (2 weeks old)	For 28 days July 22 to August 18, 2007 (2 to 6 weeks old)
Control group	14	7	21	Compound feed for fattening broilers	Compound feed for fattening broilers
10% DDGS group	13	8	21		Compound feed for fattening broilers + 10% DDGS
20% DDGS group	11	10	21		Compound feed for fattening broilers + 20% DDGS

7. Feeding management

<1> Poultry house

In a simple prefabricated poultry house, the 21 animals were housed in a 6.48-m^2 area partitioned with plywood for each group. Wood chips were used as bedding. Natural ventilation was provided, but an electric fan and small cooling equipment were installed during the study based on the changes in the temperature and humidity.

<2> Feeding

From July 22 to 30 (when the animals were 2 to 3 weeks old), each animal was provided with 380 to 400 g of feed. From July 31 to August 18 (when the animals were 3 to 6 weeks old), each animal was given 430 to 450 g of feed. Feed was offered twice daily. The amount of feed was adjusted by weighing the residual food daily at 9 a.m. and 4 p.m.

<3> Water supply

Water pipes were laid and the animals were provided with water from a nipple-type water dispenser *ad libitum*.

8. Parameters and analytical methods

<1> Analysis of the ingredients of the test diets

Each test diet was analyzed for the 5 general ingredients, calcium, and phosphorus by the official method of analysis of feed based on the Law Concerning Safety Assurance and Quality Improvement of Feed. The amount of phytate phosphorus in each test diet was measured and the

available phosphorus content was calculated by subtracting the amount of phytate phosphorus from the total phosphorus content.

<2> Measurement of the temperature and humidity of the poultry house
Temperature and humidity of the poultry house were measured daily at 9 a.m. and 4 p.m., and their respective mean values were defined as the mean values of the day.

<3> Measurement of feed intake
The provided feed and residual feed were weighed daily at 9 a.m. and 4 p.m. for each group. Daily feed intake was calculated as the difference in weight between the feed that was supplied and the residual feed.

<4> Measurement of body weight
Individual animals were weighed weekly at a fixed time.

<5> Collection of feces and measurement of phosphorus
In each group, fresh excreta of 5 specified animals were individually collected a total of 3 times, i.e., 2 days, 2 weeks, and 4 weeks after the start of the study. The concentration of total phosphorus in excreta was measured by the ammonium vanadomolybdate method with a spectrophotometer (DU530 Beckman).

<6> Measurement of the weight of cut meat and fat content
On completion of the housing period, all animals were euthanized by exsanguination. Then, the following parameters were measured in 10 animals of each group: body weight at slaughter, weights of the edible part, boneless carcass, wings, breast with bone, boneless breast, thighs with bones, and boneless thighs, liver, and peritoneal adipose tissue. Crude fat contents in the liver and peritoneal adipose tissue were also measured to calculate the accumulation of fat in the liver and peritoneal tissue.

<7> Measurement of the colors of meat, leg, and organs
The L-value (lightness), a-value (redness), and b-value (yellowness) of muscles of the right thigh and right breast, the skin of the right leg, liver, and peritoneal adipose tissue of 10 animals in each group were measured with a color meter (ZE-2000 Nippon Denshoku Industries Co., Ltd.).

<8> Measurement of the composition of fatty acids in the test diets and products

After the test diets, breast, thigh, and intraperitoneal fat were methyl-esterified, and the composition of their fatty acids was determined with a gas chromatograph (GC-2010 Shimadzu Corporation).

<9> Statistical analysis

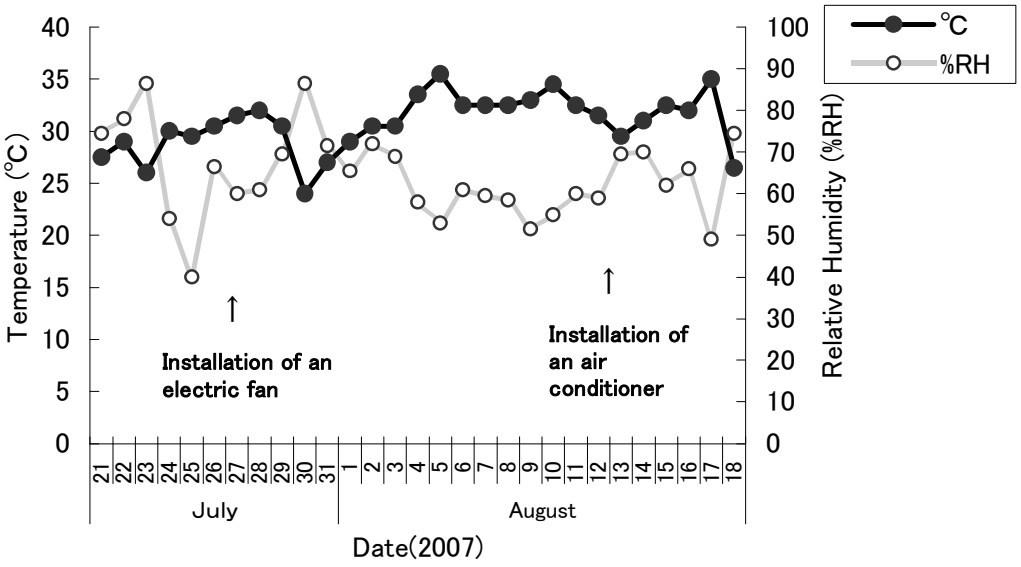
All data were subjected to one-way analysis of variance. If a significant difference was noted, Tukey's multiple comparison test was performed.

III. Results and Discussion

1. Temperature and humidity

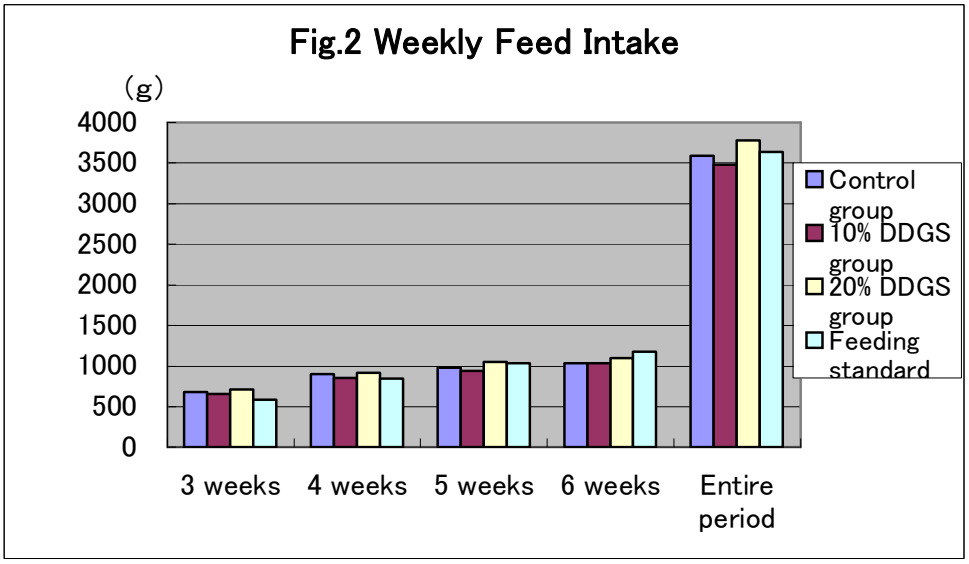
Figure 1 shows the changes in temperature and humidity, which were the parameters of the environmental conditions for housing the broilers. In the summer of 2007, when this study was conducted, it was record-breakingly hot all over Japan. As the poultry house was a simple, prefabricated one, we attempted to control the environmental conditions by introducing an electric fan and then an air conditioner instead of providing natural ventilation. In the poultry house, however, the daily mean temperature was 25°C or more throughout the housing period, and the mean temperature was the maximum (35°C or more) on August 5. The relative humidity was also high. It was 65% RH or more during the housing period. Many of the animals showed panting (breathing with their beaks open) due to the summer heat. Thus, the results achieved by the present study were obtained under the summer heat.

Fig. 1 Changes in the Mean Temperature and Mean Humidity during Housing



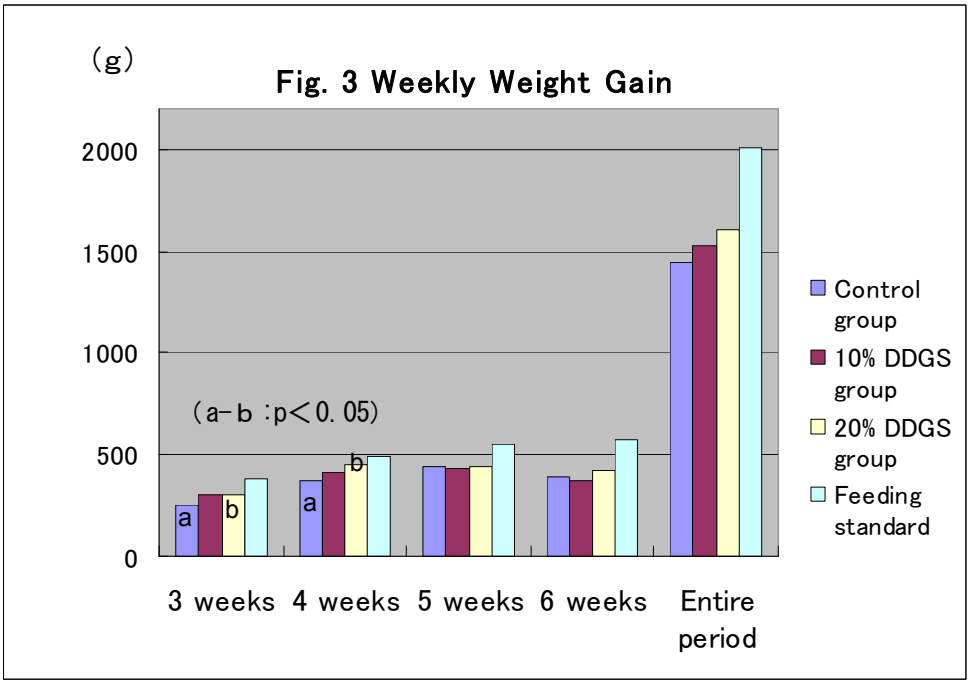
2. Feed intake

Figure 2 illustrates the changes in weekly feed intake. DDGS content in the feed did not affect feed intake throughout the feeding period. Thus, it was shown that DDGS did not cause a reduction in feed intake even during the summer heat. When compared with the standard feed intake for broilers by age (week) specified in the Japanese Feeding Standard, feed intake was higher in all groups in the early fattening period, while it was slightly lower during the last week.

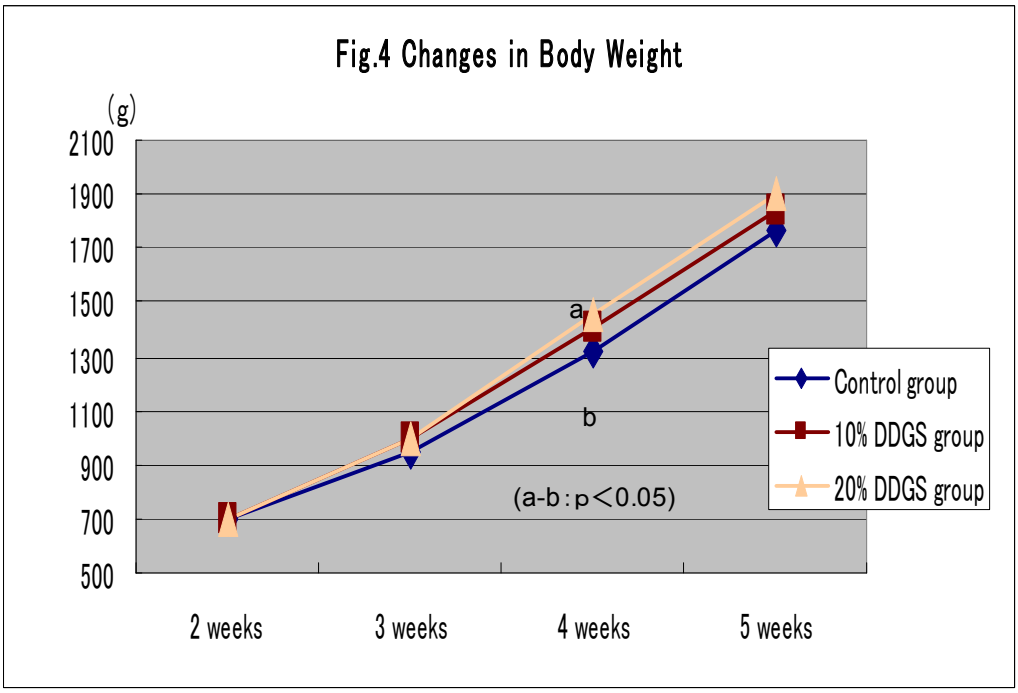


3. Growth

Fig. 4 indicates the changes in the body weight and Fig. 3 summarizes the weekly weight gain. These figures indicate that the higher the proportion of DDGS in the diet, the greater the weight gain in the early fattening period (when the animals were 3 and 4 weeks old). Weight gain was significantly higher ($p<0.05$) in the 20% DDGS group than in the control group during this period. This seems to be an effect of the higher crude protein contents in the diets (18.0, 18.9, and 19.6%) due to the higher percentages of DDGS in the diets. There were no significant differences in weight gain in the late fattening period. For the entire feeding period, weight gain tended to be higher according to the proportion of DDGS in the diet, but there were no significant differences.

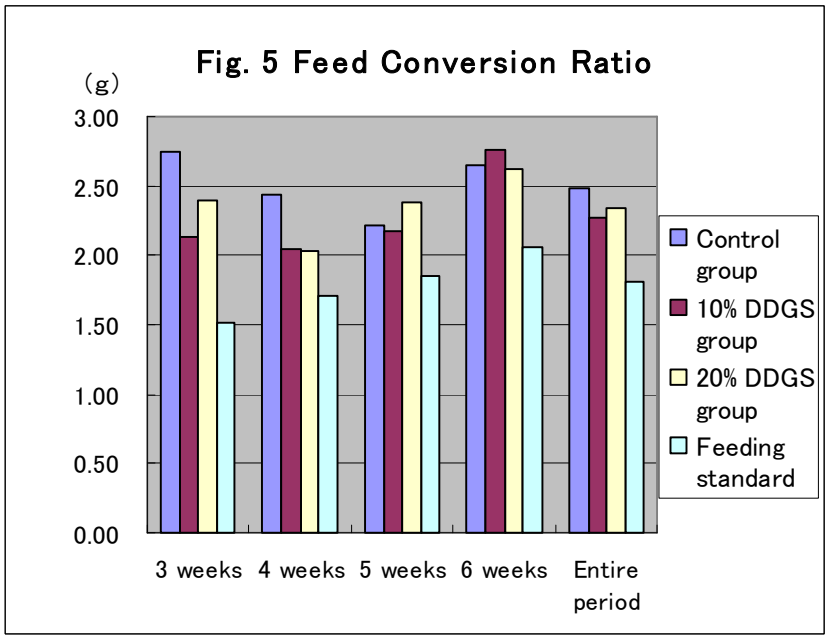


Because of the higher weight gain during the early fattening period, body weight was significantly higher ($p<0.05$) in the 20% DDGS group than in the control group when the animals were 4 weeks old. When compared with the standard weight gain specified in the Japanese Feeding Standard, weight gain was lower at all ages in all groups tested in the present study. Accordingly, in this study, the weight gain for the entire feeding period and the final body weight were lower than their respective standard values. This seems to be an influence of the summer heat.



4. Feed conversion ratio

Figure 5 presents the changes in the feed conversion ratio. In the early fattening period, the higher the percentage of DDGS in the diet, the greater the weight gain, though the feed intake was similar. Therefore, during this period, the feed conversion ratio was lower in the groups given diet containing DDGS. This finding suggests that DDGS improves economic efficiency of feed. The feed conversion ratio tended to be higher in the late fattening period, while it was still lower for the entire feeding period in the groups given diet containing DDGS.



5. Phosphorus concentrations in excreta

Containing relatively high percentages of highly available phosphorus (nonphytate phosphorus), DDGS is expected to reduce the phosphorus content excreted in feces and thus reduce the environmental burden. In the present study, the basal diet contained phytase, but not calcium phosphate. The test diets contained reduced amounts of phytase according to the increase in the amount of DDGS so that all diets contained similar percentages of available phosphorus.

Table 4 Contents of Diffent Types of Phosphorus in the Test Diets

		Control group	10%DDGS group	20%DDGS group
Total Phosphorus	%	0.64	0.65	0.64
Phytate Phosphorus	%	0.24	0.23	0.22
Available Phosphorus (Total phosphorus – Phuytate phosphorus)	%	0.40	0.42	0.42
Percentage of available phosphorus (Available phosphorus/total phosphorus)	%	62.5	64.6	65.6

Table 4 lists the composition of phosphorus contained in the diets used in the study. Available phosphorus was calculated by subtracting phytate phosphorus from total phosphorus. The available phosphorus ratio, which was calculated as the percentage of available phosphorus in total phosphorus, tended to increase (62.5, 64.6, and 65.6%) according to the proportion of DDGS in the diet, although the phytase content was reduced according to the increased percentage of DDGS in the diet.

Fig. 6 Changes in the Fecal Phosphorus Concentration

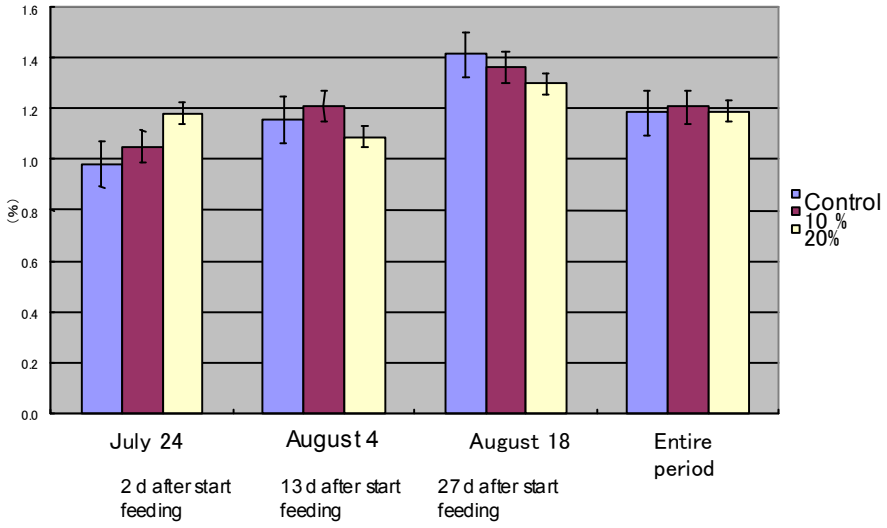


Figure 6 presents the changes in the phosphorus concentration in excreta. When the animals were 2 weeks old, the phosphorus concentration was the lowest in the basal diet group, while it increased according to the proportion of DDGS in the diet. In contrast, at the end of the fattening period when the animals were 6 weeks old, the phosphorus concentration decreased according to the proportion of DDGS in the diet. However, there were no statistically significant differences between the groups at any time.

In the present study, the percentage of DDGS in the diet, the age of the animals, and the amount of phytase added to the diet seem to have influenced the fecal phosphorus concentration. However, the fecal phosphorus concentration was found to be similar for the entire period even when reduced amounts of phytase were added to the diets. It is considered that a definite inverse correlation will be shown between the DDGS content in the diet and phosphorus excretion when

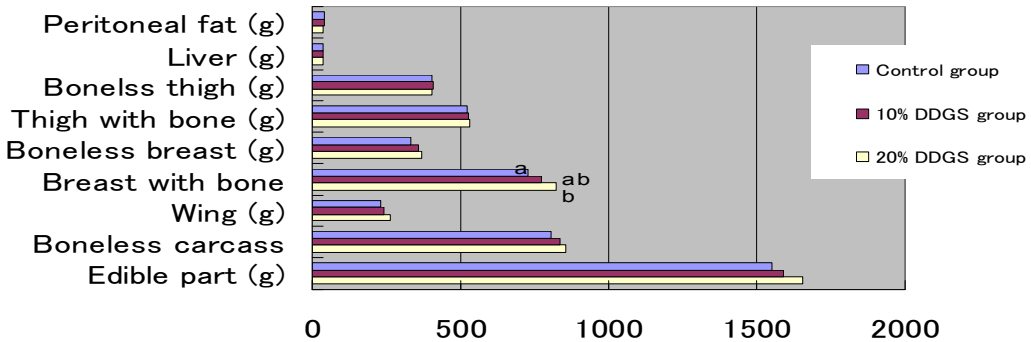
phytase is not added to the diet.

6. Weight of cut meat

Figure 7 shows the weight of cut meat. Body weight on completion of the study tended to be higher according to the percentage of DDGS in the diet, and the weight of the edible part also tended to be higher accordingly. The weights of the boneless carcass, wings, breast with bone, boneless breast, thighs with bones, and boneless thighs also tended to be higher according to the percentage of DDGS in the diet. There was a significant difference ($p<0.05$) in the weight of breast with bone between the control group and the 20% DDGS group. This seems to be an influence of the higher crude protein contents in the diets (18.0, 18.9, and 19.6%) due to the higher percentages of DDGS in the diets.

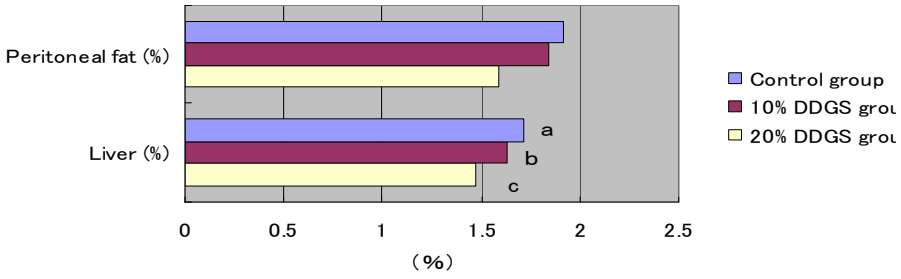
Liver weight tended to be lower (38, 36, and 34 g) according to the increase in the content of DDGS in the diet. There was a similar tendency in the weight of adipose tissue (41, 41, and 38 g), but no statistically significant differences were noted in either the liver weight or the weight of adipose tissue. The lower the ratio of liver weight (%) relative to the body weight, the higher the proportion of DDGS in the diet (Fig. 8). Specifically, the ratio was evidently smaller in the 10% DDGS group than in the control group ($p<0.05$), and was clearly smaller in the 20% DDGS group than in the 10% DDGS group ($p<0.05$). There was an even greater difference between the control group and the 20% DDGS group (1.72% vs. 1.47%, $p<0.01$). These differences are considered to be an influence of the lower metabolizable energy contents in the feed (3160, 3135, 3117 Mcal/kg) associated with the higher proportions of DDGS in the diets.

Fig.7 Weight of Cut Meat



a and b Signficantdffeences weredetected between thevalues with dfferent lettes (p<005)

Fig. 8 Proportion of the Weight of the Liver and Perioneal Adipose Tissue to the Body Weight



(a-c；p＜0.01、a-b, b-c；p＜0.05)

7. Fat accumulation

Table 5 and 6 summarize the fat content and the amount of accumulated fat (obtained by multiplying the organ weight by the fat content) in the liver and peritoneal adipose tissue, as well as the ratio of the total amount of accumulated fat in these two organs to the body weight.

Table 5 Weight of the Liver and Peritoneal Fat and Their Fat Content

	Liver		Peritoneal fat	
	Tissue weight (g)	Fat content (%)	Tissue weight (g)	Fat content (%)
Control group	37.6±1.1	4.3±1.5[a]	40.8±3.4	86.8±2.1
10%DDGS group	35.7±1.1	3.0±1.4[a]	40.7±3.3	88.4±2.3
20%DDGS group	34.4±1.1	2.0±0.8[b]	37.6±3.2	87.7±4.5

a,b:Significant diffences were detected between the values with different letters（p＜0.05）

Table 6 Amount of Fat Accumulated in Organs

	Liver＊ (g)	Peritoneal Fat＊ (g)	Ratio to the body weight at slaughter＊＊ (%)
Control group	1.63±0.58[a]	34.68±10.28	1.67±0.46
10%DDGS group	1.10±0.52[b]	36.90±8.83	1.69±0.27
20%DDGS group	0.68±0.31[c]	33.39±13.31	1.43±0.51

＊Amount of fat in the tissue:Tissue weight x ratio of crude fat
＊＊Ratio to the body weight at slaughter: (Amount of liver fat + amount of peritoneal fat)/body weight at slaughter x100
(a-c; $p<0.01$、a-b, b-c; $p<0.05$)

Clearly the lower the fat content in the liver, the higher the content of DDGS in the diet. Since liver weight tended to be lower according to the increase in the proportion of DDGS in the diet, the amount of fat accumulated in the liver for the 20% DDGS group was less than half that for the control group (1.63 vs. 0.68 g; $p<0.01$). This seems to be related to the content of metabolizable energy (ME) in the feed. The ratio of DDGS in the feed did not influence the accumulation of fat in the peritoneal adipose tissue. Thus, this study has indicated that the mechanism of lipid metabolism differs between the liver and the peritoneal adipose tissue and that the lower ME resulting from feeding DDGS to animals reduces fat accumulation in the liver.

8. Colors of the leg, meat, and organs

Table 7 lists the results of the determination of the hues of the leg, meat, and organs. In the leg, the higher the percentage of DDGS in the diet, the lower the lightness, while redness and yellowness were both similar. Macroscopically, the leg was a slightly thicker yellow. In the thigh, the higher the lightness, the lower the redness, and the higher the yellowness. In the breast, contrary to the thigh, the lower the lightness, the higher the redness, and the lower the yellowness. In the liver, as in the case of the breast, the higher the proportion of DDGS in the diet, the lower the lightness, the higher the redness, and the lower the yellowness.

DDGS is rich in red and yellow dyes from lutein and zeaxanthin in corn and it has been shown to increase the yellowness of chicken egg yolk. Thus, DDGS was expected to affect the color

of broiler meat. This study was conducted to determine whether this was the case. According to the results, there were only slight differences in hue that were rather difficult to detect with the naked eye when meat was placed side by side, although significant differences were noted by mechanical measurement. It should be determined in future studies whether these differences in hue affect the commercial value of broilers.

Table 7 Hues of the Leg, Meat, and Organs

7-1 Lightness (L-value)

Group	Leg	Thigh	Breast	Liver	Intraperitoneal fat
Control	71.89±0.78A	43.79±0.57A	43.64±0.70a	38.03±1.00A	70.20±0.52A
DDGS 10%	70.30±0.74AB	45.54±0.54AB	42.36±0.67ab	32.87±0.96B	69.63±0.50A
DDGS 20%	68.77±0.73B	46.96±0.53B	40.79±0.66b	30.79±0.94B	67.28±0.49B

7-2 Redness (a-value)

Group	Leg	Thigh	Breast	Liver	Intraperitoneal fat
Control	-0.44±0.46	4.87±0.37a	1.14±0.22A	14.64±0.30a	1.73±0.38
DDGS 10%	0.41±0.44	3.47±0.35b	0.40±0.21AB	13.90±0.29ab	0.77±0.36
DDGS 20%	0.14±0.43	3.33±0.35b	0.06±0.21B	13.34±0.29b	0.90±0.36

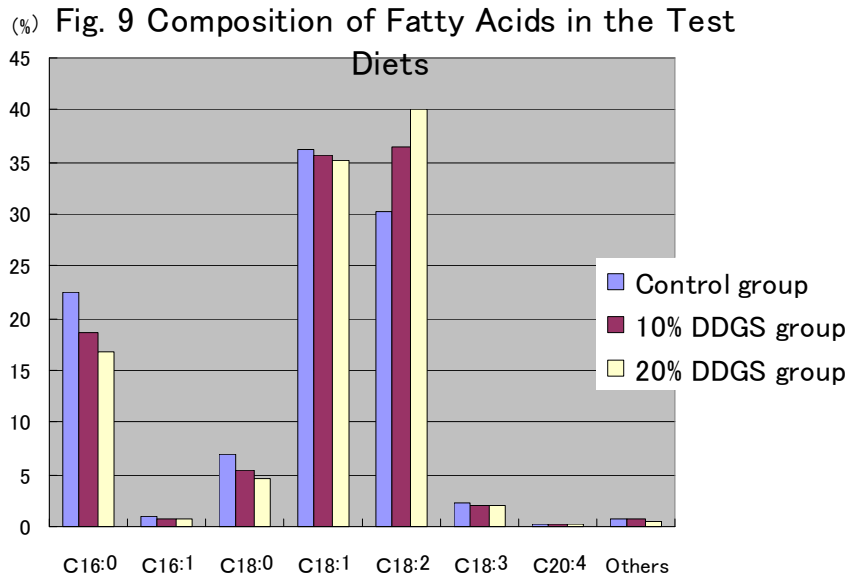
7-3 Yellowness (b-value)

Group	Leg	Thigh	Breast	Liver	Intraperitoneal fat
Control	29.88±0.74	7.48±0.30A	7.45±1.08	13.79±0.51a	15.53±0.39a
DDGS 10%	29.21±0.70	8.27±0.28AB	6.17±1.03	11.71±0.49b	16.80±0.37ab
DDGS 20%	28.49±0.69	8.78±0.28B	6.22±1.02	11.22±0.48B	17.05±0.36b

(Significant differences were detected between the values with different letters. A – B and a – B, $p<0.01$; a – b, $p<0.05$)

9. Composition of fatty acids

DDGS contains fat derived from corn at high concentration. Therefore, the higher the proportion of DDGS in the diet, the closer the composition of fatty acids is to that of corn oil. Table 8 shows the composition of fatty acids in the fats and oils contained in the test diets.

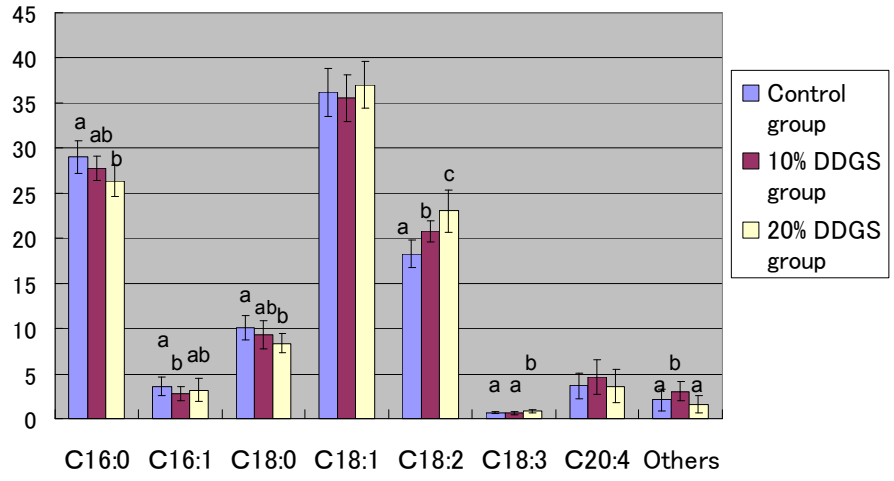


Since the basal diet contains animal oils and fats, the feed for the control group is relatively rich in saturated fatty acids C16:0 (palmitic acid) and C18:0 (stearic acid). Since corn oil is rich in C18:2 (linoleic acid), the higher the percentage of DDGS in the diet, the lower the percentages of palmitic acid and stearic acid and the markedly higher the proportion of linoleic acid became, as is shown by the Fig.9.

Figures 10 to 12 illustrate the composition of fatty acids in the breast, thigh, and peritoneal adipose tissue obtained by feeding the test diets to the animals. It was found that the composition of fatty acids in the fats of all these tissues reflected the composition of fatty acids contained in the diets. Specifically, the higher the proportion of DDGS in the diet, the lower the percentages of saturated fatty acids, palmitic acid and stearic acid became. According to the increase in the content of DDGS, the percentages of unsaturated fatty acids C16:1 (palmitoleic acid) and C18:1(oleic acid) tended to be lower, and particularly, that of linoleic acid was markedly higher.

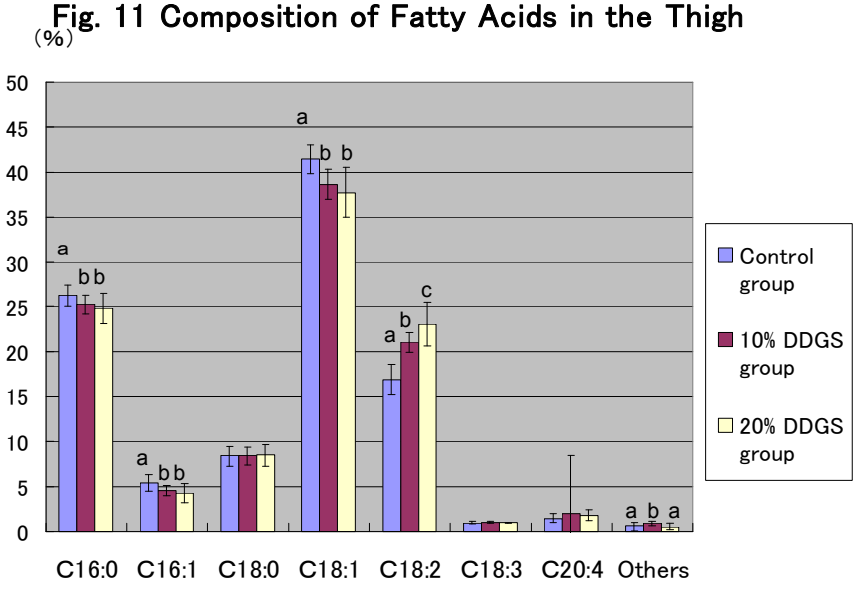
The composition of fatty acids in body fat of broilers is also important from the perspective of industry because it affects not only the taste of meat, but also the life of frying oil for fried chicken. It is noteworthy that the composition of fatty acids in body fat becomes closer to that of plants when animals are fed DDGS. The evaluation of this observation requires future discussion with the related industries.

Fig. 10 Composition of Fatty Acids in Breast

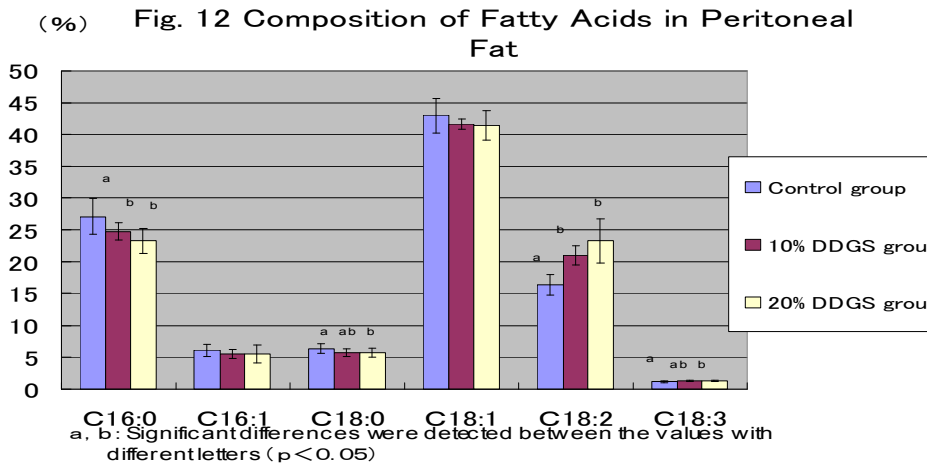


a, b, c: Significant differences were detected between the values with different letters ($p<0.05$)

Fig. 11 Composition of Fatty Acids in the Thigh



a, b: Significant differences were detected between the values with different letters ($p<0.05$)



IV. Summary

1. To assess the effect of corn distiller's dried grains with solubles (DDGS) produced in the U.S. on the meat production and their quality, such as accumulation of peritoneal fat, composition of fatty acids, meat color, and fecal phosphorus concentration, we conducted a study in a commercial domestic breed of broilers (Chunky) in the Laboratory of Animal Nutrition, Nippon Veterinary and Life Science University (Tokyo).

2. A total of 63 broilers in the following 3 groups (21 animals per group) were fattened for 4 weeks: the control group, which was given a commercial feed for fattening broilers, and the test groups, which were given a diet containing 10% or 20% DDGS (outer percentages). This study was conducted under summer heat conditions between July and August 2007.

3. The higher the content of DDGS in the diet, the higher the protein content and the lower the metabolizable energy. The test diets were prepared so that they contained the same percentages of lysine and available phosphorus by adding adjusted amounts of lysine alone and phytase accordingly.

4. The concentration of phytase in the diet was reduced according to the increase in the content of DDGS. The concentration of phosphorus in excreta tended to be higher in the early fattening period and to be lower in the late fattening period, but was similar for the entire period. This finding indicates that fecal phosphorus concentrations were similar for the entire period when

reduced amounts of phytase were added.

5. The higher the content of DDGS in the diet, the better the growth performance in the early fattening period became, though feed intake was similar, and the feed conversion ratio was better. This seems to be due to the higher crude protein contents in the diets.

6. In response to the slightly higher weight gain due to the higher contents of DDGS in the diets, the production of cut meat tended to be higher in the groups given diet containing DDGS. Accordingly, the higher the content of DDGS in the diet, the lower the weights of the liver and peritoneal adipose tissue, and clearly the smaller the amount of fat accumulated in the liver. This seems to be due to the lower metabolizable energy in the feed.

7. The higher the proportion of DDGS in the diet, the lower the lightness of the leg skin color, the higher the redness of the breast meat, and the higher the yellowness of the thigh meat, but the differences were difficult to detect with the naked eye.

8. The higher the percentage of DDGS in the diet, the lower the proportions of saturated fatty acids (abundant in animal fats and oils) in the diet, and the markedly higher the content of linoleic acid (abundant in corn), an unsaturated fatty acid. This change in the composition of fatty acids in the feed was reflected in the composition of fatty acids in the meat and adipose tissue of the broilers; the product was obviously rich in linoleic acid.