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ORIGINAL ARTICLE

Effects of feeding dried distillers grains with solubles (DDGS) on meat quality at the late stage of the fattening period of Holstein steers

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ABSTRACT

Feeding dried distillers grains with solubles (DDGS) during the late stage of the fattening period of Holstein steers was studied in regard to the influence on meat quality. Sixteen Holstein steers approximately 18 months old were used in this study. Eight animals were fed commercial concentrated feed for the entire fattening period. The other eight animals were fed 15% DDGS in the concentrated feed for 3 months before slaughtering. The moisture, ether extract and crude protein from both groups was approximately the same. The thiobarbituric acid reactive substance (TBA) value of storage for 7 days at 5°C from the animals fed DDGS showed a tendency to be lower ($P = 0.059$). The change in the TBA value during storage was also lower for the animals not fed DDGS ($P < 0.05$). There were no differences in the subcutaneous fat color between the two groups. The a*(measure of redness) and b*(measure of yellowness) of the M. longissimus from the animals fed DDGS showed a tendency to be lower ($P = 0.051$, 0.070). The fatty acid composition of the M. longissimus, subcutaneous and perirenal fat were not widely influenced by the feeding of DDGS. It is suggested that feeding 15% DDGS during the late stage of the fattening period for Holstein steers reduced the oxidation of the beef.

Key words: *DDGS, Holstein steers, meat quality.*

INTRODUCTION

Energy production that considers the environment is currently being investigated. The production of bio-ethanol from plants is on the rise. Especially, bio-ethanol production from corn is becoming popular in the United States. Bio-ethanol is produced by fermenting and distilling the starch in the corn, and during production dried distillers grains with solubles (DDGS) are produced as a by-product. The DDGS from bio-ethanol using corn includes rich protein, fat and fiber, and its value as a feed for animals is high (Kimura & Takahashi 2007). DDGS has a high level of unsaturated fatty acid and contains vitamin E (National Agricultural Research Organization 2001; Takahashi *et al.* 2008) because DDGS is produced to remove starch from corn, like concentrated corn without starch. There are many reports about DDGS fed to animals in the United States. In Japan, the price of DDGS is becoming lower because of improvements in the method of transport. Recently, a lot of DDGS has been imported, fed to dairy cattle, swine and poultry on a commercial basis in Japan. However, the feeding of DDGS to beef cattle is rare. Japanese beef cattle, which have a later slaughter age than that of North American and European beef cattle, have been the subject of few reports concerning the feeding of DDGS as a fattening method. Recently, the beef industry and consumers in Japan have been interested in beef quality. The maintaining of good quality is an important factor for retail meat. Beef from Holstein steers is distributed at a lower price in comparison to Wagyu beef and cross-bred beef because of the lower level of beef quality, but they are important to meet the demand for the production of ordinary beef in Japan. For this reason, beef from Holstein steers has to be produced at a low cost. Furthermore, Holstein beef which competes with imported beef in price has to have added value in comparison to imported beef.

The effects of feeding DDGS for 3 months before slaughtering during the fattening period on the beef

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qualities of Holstein steers were examined in this study.

MATERIALS AND METHODS

Animals

The animals were managed on a private commercial farm, Akiyoshidai Beef Farm, in Yamaguchi prefecture and cared for according to the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (Consortium 1988).

The animals included 16 Holstein steers approximately 18 months old (DDGS group, 17.5 months; Control group, 17.2 months). Eight animals were assigned to a test group that was fed DDGS made in Wisconsin, USA (KANEMATSU CORPORATION Ltd, Tokyo, Japan), in the concentrated feed for 3 months before slaughtering (DDGS group). The other eight animals were assigned to a control group that were fed a concentrated feed not containing DDGS for all periods during the fattening period (Control group). The animals of the DDGS group were fed concentrated feed containing actual 15% DDGS and 85% concentrated feed which matched that of the Control group. The animals from each group were managed in separate pen. All other management aspects during the fattening period were the same for the two groups.

Animal feed

An outline of the DDGS used for the DDGS group, and the concentrated feed and the hay for the two groups is shown in Table 1. The concentrated feed used in this study was commercially sold (NICHIWA SANGYO Co, Ltd, Hyogo, Japan), 66% grains of mainly corn, 23% bran of mainly wheat bran and 9% oil meals of mainly soy bean oil bran. The crude protein and ether extract in the concentrated feed for the DDGS group was higher than those for the Control group because of the addition of DDGS, and the differences between the two groups were 2.16% and 1.59% (dry matter (DM)%), respectively. The nitrogen-free extracts (NFE) and total digestible nutrient (TDN) in the DDGS group was 1.01% and 0.31% (DM%) less compared to the Control group, and there were no big differences. The vitamin E content in DDGS used in this study was 10.3 mg/100 g. The vitamin E in concentrated feed for the DDGS group was 3.2 mg/100 g as a result of the 15% DDGS compared to the concentrated feed for the Control group. The Control group was 1.9 mg/100 g of vitamin E.

The fatty acid composition in the concentrated feed for the two groups was approximately the same (Table 2). The linoleic acid (C18:2) content was the highest in the fatty acid of the concentrated feed for the two groups and was 51.86% and 51.18%, respectively. The concentrated feed intakes of the two groups were measured every day in each pen and were calculated each month without data statistics. The hay fed was timothy, and the animals in the two groups were fed approximately 1.0 kg/day. The vitamin E in hay for the two groups was 3.8 mg/100 g.

The animals in the DDGS group were fed the concentrate which included 5–10% DDGS for 10 days before the test period for acclimatization to the DDGS.

Table 1 Chemical composition of the dried distillers grains with solubles (DDGS) and concentrated feed and hay used in this study

	DDGS	DDGS group	Control group	Timothy
Concentrated feed (%)	–	85	100	–
DDGS (%)	–	15	0	–
Moisture (%)	7.90	8.75	8.90	9.20
Crude protein (DM%)	28.66	16.43	14.27	9.20
Ether extract (DM%)	12.84	3.79	2.20	1.40
NFE (DM%)	45.96	51.67	52.68	47.30
Crude fiber (DM%)	7.33	10.43	10.98	33.00
Crude ash (DM%)	5.21	10.11	10.98	8.90
TDN (DM%)	78.07	79.82	80.13	66.30
Vitamin E (mg/100 g)	10.30	3.20	1.90	3.80

This data was calcurated using Standard Table of Feed Composition in Japan National Agricultural Research Organization (2001). NFE, nitrogen-free extracts; TDN, total digestible nutrients; DM, dry matter.

Body weight

The animal's body weight was measured once a month. The daily gains for each month and the average daily gains during the period of feeding the DDGS feed were calculated.

Vitamin E in feed

The original feed was pyrogallol and saponificated by potassium hydrate. Then, vitamin E was abstracted with hexane, 2-puropanole and acetic ester (9:1.5:1, V/V/V). The vitamin E was analyzed by high-pressure liquid chromatography (HPLC) with a fluorescence detector of 325 nm (RF-10AXL; Shimadzu, Kyoto, Japan) (Ujiie *et al*. 1991; Ministry of Health, Labour and Welfare of Japan 1999).

Meat quality

The animals were slaughtered at the age of approximately 21 months (DDGS group, 21.4 months; Control group, 21.3 months) at a slaughterhouse in Houfu city, Yamaguchi. The carcasses were cooled at 1°C for approximately 1 day and dissected by a commercial method. A part of the M. longissimus and subcutaneous fat on the seventh and 13th rib-bones and the perirenal fat were removed for analysis and vacuum-packed. The samples were transported under refrigeration to the Nippon Veterinary and Life Science University, Tokyo, and analyzed as follows. The refrigerated M. longissimus was analyzed for moisture, ether extract, crude protein and meat color. A sample of the remainder was

Table 2 Fatty acid composition of the dried distillers grains with solubles (DDGS) and concentrated feed used in this study

	DDGS	DDGS group	Control group
C14:0 (%)	0.06	0.55	0.64
C14:1 (%)	0.01	0.43	0.51
C16:0 (%)	13.91	16.05	16.29
C16:1 (%)	0.05	0.14	0.16
C17:0 (%)	0.08	0.00	0.00
C18:0 (%)	2.43	2.51	2.53
C18:1 (%)	25.89	25.28	25.17
C18:2 (%)	55.69	51.86	51.18
C18:3 (%)	1.23	3.18	3.52
US/S	5.03	4.23	4.14

US/S, total unsaturated fatty acid/total saturated fatty acid.

frozen and used for analyzing the thiobarbituric acid reactive substance (TBA) value and fatty acid composition. The refrigerated subcutaneous fat was measured for fat color. The subcutaneous fat of the remainder was analyzed for fatty acid composition after freezing at −20°C.

Concerning the moisture in the M. longissimus, the sample was dried at 105°C for 24 h and was calculated using the difference in sample weight before and after drying. The ether extract was analyzed using the Soxhlet method with diethyl ether for 16 h. The crude protein was analyzed using the Kjeldahl method (Okumura *et al*. 2007). The TBA value of M. longissimus was analyzed using a distillation method (Tarladgis *et al*. 1960; Shibata & Kinumaki 1979), and the values at just after defrosting, and storing for 7 days at 5°C after defrosting, were analyzed. The difference between just after defrosting and storing was then examined. The colors of the subcutaneous fat and M. longissimus on the 7th rib-bone were measured using a spectrophotometer with an 8 mm aperture (CM700d; KONICA MINOLTA, Osaka, Japan), and the L*(measure of lightness), a*(measure of redness) and b*(measure of yellowness) values were evaluated. The color of the M. longissimus was measured at both 1 h and 48 h after cutting and in contact with air at 2°C, and the differences between 1 h and 48 h were also examined. The value for each was the mean of three random readings for each sample. Concerning the fatty acid composition, the lipid in the sample was extracted with chloroform and methanol (2:1; v : v) (Folch *et al*. 1957). The lipid was soaped with potassium hydroxide (KOH), and then methyl-esterified with a boron trifluoride-methanol complex methanol solution. The methyl-ester of the fatty acid was dissolved in hexane and analyzed using gas-chromatography (GC2010; Shimadzu) and a capillary column (RT2560, 0.25 mm, 100 m; Shimadzu). The integrator was FID. The carrier gas was helium. Ten fatty acids (C14:0, C14:1, C15:0, C16:0, C16:1, C17:0, C18:0, C18:1, C18:2, C18:3) were identified at each retention-time. Six major fatty acids (C14:0, C16:0, C16:1, C18:0, C18:1, C18:2) of the ten are discussed.

Statistical analysis

The differences between the two groups regarding the meat quality were calculated using the GLM procedure of SAS (SAS 9.1.3.; SAS Institute Inc., Cary, NC, USA). In this study, when the *P*-value resulting from the calculations was less than 0.05, there is a statistical difference between the two groups.

RESULTS AND DISCUSSION

Feed intake

Table 3 shows the daily concentrated feed intakes per month for each animal from the two groups. The intakes of the two groups for the first month were approximately the same. For the second month, the DDGS group was 2.1 kg (DM 2.1 kg) less than the Control group. For the third month, the DDGS group was 0.8 kg (DM 0.5 kg) more than the Control group. The average intakes of the DDGS and Control groups during the test period were 15.0 kg (DM 13.2 kg) and 15.7 kg (DM 14.0 kg), respectively; the difference between the two groups in the actual concentrated feed intakes was 0.7 kg (DM 0.9 kg) in total. The actual concentrated feed intake of the DDGS group was slightly smaller in quantity. There were no differences in the feed intake between the higher-level DDGS feed and the lower-level DDGS feed in the previous studies which used more than 30% levels of DDGS concentrated feed (Roeber *et al*. 2005; Loy *et al*. 2008; Gunn *et al*. 2009). In the calculated TDN intake for each animal per day from the two groups, the DDGS and Control groups were 11.18 kg and 12.05 kg, respectively; and the DDGS group was 0.87 kg less than the Control group. Furthermore, the intake of vitamin E in the DDGS group during the test period was 4368.00 mg, and the Control group was 2714.53 mg according to the calculations. The DDGS group took in 1.6 times the amount of vitamin E compared to the Control group.

Table 3 Daily concentrated feed intake at each month and total for an animal

	DDGS group	Control group
First period (kg)	16.0 (14.0)	15.9 (14.1)
Second period (kg)	14.2 (12.4)	16.3 (14.5)
Third period (kg)	15.2 (13.3)	14.4 (12.8)
Whole period (kg)	15.0 (13.1)	15.7 (14.0)

Numbers in parentheses: dry matter intake. First period: 18 to19 months old. Second period: 19 to 20 months old. Third period: 20 to 21 months old. Whole period: 18 to 21 months old.

Body weight

Figure 1 shows the change in the body weight from the DDGS feeding period. The body weights of the DDGS group and the Control group at the initial time were 580.8 kg and 575.3 kg, respectively. The body weights from the two groups at the finishing time were 689.1 kg and 679.8 kg, respectively. There was no significant difference in body weight between the two groups for each month and the total period. The daily gain in body weight from the DDGS group for the third month was significantly higher than the Control

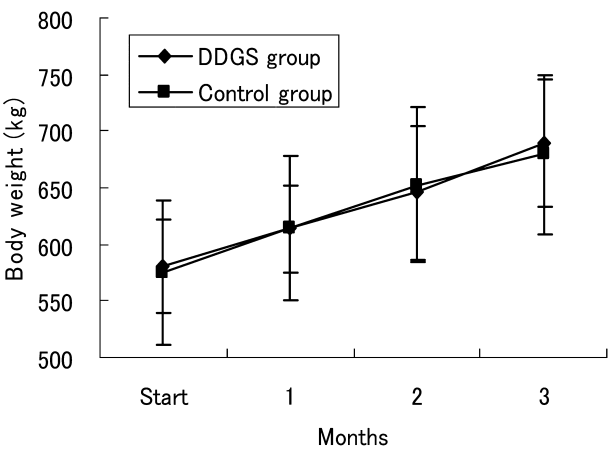

Figure 1 Change in the body weight from the dried distillers grains with solubles (DDGS) feeding period.

group ($P < 0.05$, Table 4). The daily gain of the DDGS group then fluctuated during the test period, and that of the Control group then decreased through the test period. The average daily gain through the test period of the two groups was 1.07 kg/day and 1.03 kg/day, respectively; there was no significant difference. Depenbusch *et al*. (2009) reported that feeding concentrated feed with a ratio of 15% DDGS brought the highest growth performance compared to other ratios (0, 15, 30, 45, 60, 75%) of DDGS within the feed. Leupp *et al*. (2009) reported that the ratio of DDGS (0% and 30%) did not effect growth performance. Due to the short term of this study, 3 months, the effect of 15% DDGS on overall growth was not significantly observed. However, the change of the daily gain for each month suggested a differing trend between the two groups. If the period for feeding 15% DDGS is longer, the daily gain may be significantly different between the two groups.

Chemical composition

Table 5 shows the chemical composition of the M. longissimus from the seventh rib-bone and 13th rib-bone. The ether extract, which was the most important trait in the chemical composition of beef, from the DDGS group on the seventh rib-bone was 11.70%, and the Control group was 9.97%. The DDGS group and the Control group on the 13th rib-bone were 7.59% and 6.36%, respectively. The ether extracts from the DDGS group were higher than the Control group in spite of no significant differences in the two parts. There were no differences in the moisture and crude protein of both samples between the two groups. Depenbusch *et al*. (2009) reported that marbling was not different for heifers fed different levels (0, 15, 30, 45, 60, 75%) of distillers grains with solubles ($P \geq 0.06$) for 148 days. However, Gunn *et al*. (2009) reported that the ether extract of the M. longissimus from Angus-crossbred fed concentrated feed containing 50% DDGS for approximately 3 months significantly increased in spite of small significant differences compared to that from the animals fed 25% DDGS, that is, their control group ($P < 0.05$). As a result of previous reports and the present study, feeding DDGS to beef cattle before slaughtering cannot significantly influence the chemical composition of the beef. Smith and Crouse (1984) reported that reducing the dietary starch content might decrease the marbling score. Although DDGS had a lower NFE, the ether extract in the M. longissimus from beef cattle fed DDGS was approximately the same as that for the commercial feed or slightly higher in content. The digestibility of the nutrients in DDGS would be easier compared to the other commercial concentrated feed.

TBA value

Table 6 shows the TBA value of the M. longissimus on the seventh rib-bone. There was no significant difference just after defrosting between the two groups. After storing for 7 days at 5°C, the DDGS group was 8.86 nmol MDA/g, and the Control group was 13.71 nmol MDA/g; thus, the DDGS group showed a tendency to be lower than the Control group ($P = 0.059$). Concerning the differences between just after defrosting and storing, the DDGS group was 8.00 nmol MDA/g, and the Control group was 13.29 nmol MDA/g; thus, there was a significant difference between the two groups ($P < 0.05$). Gunn *et al*.

Table 4 Daily gain at each month and total for an animals fed dried distillers grains with solubles (DDGS)

	DDGS group	Control group	Significance
First period (kg)	1.13 ± 0.31†	1.34 ± 0.36	ns
Second period (kg)	0.84 ± 0.65	1.01 ± 0.35	ns
Third period (kg)	1.28 ± 0.39	0.80 ± 0.30	*
Whole period (kg)	1.07 ± 0.18	1.03 ± 0.19	ns

*$P < 0.05$. †Mean ± standard diviation. ns, not significant ($P > 0.05$). First period: 18 to19 months old. Second period: 19 to 20 months old. Third period: 20 to 21 months old. Whole period: 18 to 21 months old.

Table 5 Mosture, ether extract and crude protein in the M. longissimus from the animals fed dried distillers grains with solubles (DDGS)

	DDGS group	Control group	Significance
On the seventh rib-bone			
Moisture (%)	67.09 ± 2.74†	68.61 ± 2.06	ns
Ether extract (%)	11.70 ± 3.43	9.97 ± 2.81	ns
Crude protein (%)	19.74 ± 0.84	19.80 ± 0.68	ns
On the 13th rib-bone			
Moisture (%)	69.64 ± 1.81	71.14 ± 2.44	ns
Ether extract (%)	7.59 ± 2.34	6.36 ± 2.76	ns
Crude protein (%)	21.12 ± 0.63	20.80 ± 0.72	ns

†Mean ± standard diviation. ns, not significant ($P > 0.05$).

Table 6 Thiobarbituric reactive substances value just after thawing and storing in the M. longissimus on the seventh rib-bone from the animals fed dried distillers grains with solubles (DDGS)

	DDGS group	Control group	Significance
Just after defrosting (nmol MDA/g)	0.75 ± 0.89†	0.38 ± 0.52	ns
Storing for 7 days (nmol MDA/g)	8.86 ± 5.40	13.71 ± 2.98	ns
Changing for 7 days (nmol MDA/g)	8.00 ± 5.48	13.29 ± 3.25	*

*$P < 0.05$. †Mean ± standard deviation. Changing for 7 days: difference between just after defrosting and storing for 7 days. ns: not significant ($P > 0.05$).

Table 7 Subcutaneous fat and m. longissimus color from the animals fed dried distillers grains with solubles (DDGS)

	DDGS group	Control group	Significance
Subcutaneous fat color			
L*	77.90 ± 6.74†	78.04 ± 4.36	ns
a*	0.44 ± 1.72	0.57 ± 0.98	ns
b*	7.61 ± 1.89	7.29 ± 0.89	ns
M. longissimus color			
1 h after touching air			
L*	42.00 ± 3.59	41.85 ± 1.09	ns
a*	20.07 ± 3.21	22.52 ± 1.18	ns
b*	16.90 ± 1.76	18.38 ± 0.66	ns
48 h after touching air			
L*	42.99 ± 3.33	42.80 ± 2.47	ns
a*	21.95 ± 1.91	23.11 ± 0.83	ns
b*	17.77 ± 1.00	18.48 ± 0.41	ns
Changes between 1 h and 48 h			
L*	0.99 ± 1.82	0.95 ± 1.63	ns
a*	1.88 ± 3.16	0.59 ± 1.40	ns
b*	0.87 ± 1.46	0.10 ± 0.85	ns

†Mean ± standard diviation. ns, not significant ($P > 0.05$). L* (measure of lightness), a* (measure of redness), b* (measure of yellowness).

(2009) reported that the TBA value from ground toproud samples after defrosting did not differ due to the dietary treatment of DDGS (25%DDGS(Control) and Control +50%DDGS). There was also no significant difference just after defrosting between the two groups in the present study. However, there was a difference after storage between the two groups. Feeding DDGS inhibited the lipid oxidation in the beef in storage. The Standard Tables of Feed Composition in Japan (National Agricultural Research Organization 2001) and a previous report (Takahashi *et al*. 2008) stated that DDGS contains high quantities of vitamin E. The DDGS used for this study also had a high concentration of vitamin E; the concentrated feed for the DDGS group had 1.7 times the amount of vitamin E compared to that for the Control group. The animals of the DDGS group took in 1.54 times the amount of vitamin E compared to the Control group according to the calculations. Vitamin E has an antioxidant effect. Mitsumoto *et al*. 1991; 1993) reported that the change in the TBA value from beef cattle fed vitamin E was slight compared to that from non-vitamin E feed. The results of the TBA value in this study suggested that the vitamin E in the concentrated feed containing DDGS must transfer to the muscle and that the lipid oxidation in the beef is inhibited compared to the Control group. Campo *et al*. (2006) documented that the perception of rancidity and beef flavor in relation to TBA value followed a sigmoidal curve, and keeping TBA value was effective for maintenance of flavor. Feeding DDGS to Holstein steers is potentially useful for commercial applications because the Holstein beef, that is, ordinary beef, could be effectively stored for longer.

Color profile

Table 7 shows the color profile of the subcutaneous fat and the M. longissimus on the seventh rib-bone from the animals. There were no significant differences between the DDGS and Control group of L*, a* and b* values from the subcutaneous fat. Some previous studies, in which more DDGS was fed to beef cattle, also reported that by-products, such as dry distiller's grain (DDG) and wet distiller's grain (WDG) from bio-fuel with corn, do not yellow the body fat (Roeber *et al*. 2005; Gunn *et al*. 2009). DDGS and by-products produced from bio-fuel using corn do not have a bad influence, that is, a yellow color, on the body fat for commercial use.

Concerning the color profiles of the M. longissimus, 1 h after contact with air, the a* and b* values from the DDGS group showed a tendency to be lower than those from the Control group ($P = 0.051$, 0.070). After 48 h, the b* value from the DDGS group continued to

show a tendency to be lower ($P = 0.097$). Because the increasing rate of the a* value after 48 h from the DDGS group was higher than that from the Control group, there were no significant differences in the a* value between the two groups. Furthermore, the changes in color profiles after 1 h and 48 h from the DDGS group did not show significant differences from that of the Control group. Roeber *et al*. (2005) reported that DDGS and WDG in cattle finishing diets at high (40–50%) inclusion rates might have a negative effect on beef color for some color panelists. Gunn *et al*. (2009) reported that feeding 50% DDGS did not significantly influence the meat color and decreased the numerical value of a* and b* of the M. longissimus. Leupp *et al*. (2009) reported that feeding 30% DDGS to beef cattle decreased the L*, a* and b* values of loin steak compared to the feeding of dry-rolled corn. Therefore, the feeding of DDGS must decrease the a* and b* values in beef at 1 h after contact with air. Zerby *et al*. (1999) documented that visual appearance scores were moderately to highly correlated to the a* value. These results of feeding DDGS might be negative as a commodity just after cutting or display. However, there might be no problem as a commodity in a 48 h display. Zerby *et al*. (1999) reported that the a* value of beef from cattle fed vitamin E was higher compared to the cattle with non-vitamin E feed, and based on the result of the TBA value in this study, feeding DDGS containing vitamin E would not decrease the quality of beef during storage.

Fatty acid composition

Table 8 shows the fatty acid composition of the M. longissimus and subcutaneous fat on the seventh rib-bone and the perirenal fats. There were no significant differences in the M. longissimus and the subcutaneous fat between the two groups. The rates of unsaturated fatty acid and saturated fatty acid (US/S) from the M. longissimus and subcutaneous fat were also not different. Palmitoleic acid (C16:1) of the perirenal fat from the DDGS group showed a tendency to be lower than that from the Control group ($P = 0.070$). The other fatty acids from the perirenal fat were approximately the same for the two groups. Because there were no large differences in the fatty acid composition of the concentrated feed between the two groups, there were no significant differences in fatty acid composition in the three fat parts between the two groups. The C16:1 which had shown a tendency to be lower in the perirenal fat had a very small content in the concentrated feed used in this study, and the fatty acid composition in the feeds of the two groups were approximately the same. It was necessary for the fatty acid composition in the perirenal fat to be examined

Table 8 Fatty acid composition of M. longissimus, subcutaneous fat and perirenal fat from the animals fed dried distillers grains with solubles (DDGS)

	DDGS group	Control group	Significance
M. longissimus			
C14:0	3.76 ± 0.54†	3.53 ± 0.35	ns
C14:1	0.88 ± 0.29	0.68 ± 0.15	ns
C16:0	30.28 ± 1.76	30.71 ± 0.96	ns
C16:1	3.29 ± 1.76	3.55 ± 0.33	ns
C18:0	15.44 ± 2.97	14.98 ± 1.10	ns
C18:1	38.33 ± 1.79	39.44 ± 1.95	ns
C18:2	6.44 ± 2.13	5.85 ± 1.77	ns
US/S	0.97 ± 0.09	0.99 ± 0.08	ns
Subcutaneous fat			
C14:0	4.21 ± 0.55	4.10 ± 0.64	ns
C14:1	2.05 ± 0.49	1.98 ± 0.36	ns
C16:0	29.89 ± 0.80	30.21 ± 1.18	ns
C16:1	6.52 ± 1.20	7.06 ± 0.54	ns
C18:0	10.51 ± 1.67	9.86 ± 1.46	ns
C18:1	42.83 ± 2.03	43.15 ± 2.95	ns
C18:2	2.65 ± 0.48	2.81 ± 0.46	ns
US/S	1.19 ± 0.08	1.24 ± 0.14	ns
Perirenal fat			
C14:0	3.54 ± 0.63	3.55 ± 0.34	ns
C14:1	0.25 ± 0.06	0.22 ± 0.07	ns
C16:0	29.00 ± 2.18	29.00 ± 1.27	ns
C16:1	2.09 ± 0.21	2.31 ± 0.09	ns
C18:0	30.55 ± 2.21	29.40 ± 1.83	ns
C18:1	31.34 ± 2.59	32.28 ± 2.76	ns
C18:2	2.74 ± 0.49	2.75 ± 0.53	ns
US/S	0.58 ± 0.06	0.60 ± 0.07	ns

†Mean ± standard deviation. US/S; total unsaturated fatty acid/total saturated fatty acid. ns, not significant ($P > 0.05$).

thoroughly in consideration of the ingredients of the DDGS. Ishida *et al*. (1988) showed that the fatty acid composition from the perirenal fat was more influenced by the feed compared to other body fats. Duckett *et al*. (1993) reported that feeding different feed for 3 months before slaughtering influenced the ether extract and fatty acid composition in muscle, and May *et al*. (1992) reported that the carcass grade and sensory characteristics, also were influenced. Dugan *et al*. (2010) reported that feeding DDGS from wheat at levels above 40% for 133 days influenced the fatty acid composition of brisket fat and diaphragm while a 20% level of DDGS had no influence. Based on these results and this study, the fatty acid composition of general body fat was not widely influenced by using 15% DDGS feed for 3 months before slaughter, and only the perirenal fat was influenced slightly by feeding 15% DDGS.

The Ministry of Agriculture, Forestry and Fisheries (MAFF) (2007) reported that they were planning to promote the utilization of DDGS in Japan after the resolution of some problems for feeding animals and that the imported volume of DDGS had increased. Because the Japanese livestock industry imports a lot of feed from foreign countries and depends on imported feed, the MAFF is executing a policy to increase the supply of domestic feed. Massive feeding of DDGS which is imported from foreign countries is not a wise solution for Japan. In this study, the DDGS levels were smaller compared to many previous reports. Furthermore, Holstein steers are important for the production of ordinary beef in Japan but are traded at a lower price in comparison to Wagyu beef and crossbred beef because of the lower beef quality. The Holstein steer has to be fattened at a lower cost, and the beef needs to have added value. DDGS, a by-product, is a lower price feed and contains more vitamin E than imported corn. Feeding 15% DDGS which is not too high a level for Holstein steers during the late stage of the fattening period did not have any negative effects on the meat quality and showed a possibility for long-term storage and additionally can add value for Holstein beef by lowering the cost.

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REFERENCES

Campo MM, Nute GR, Hughes SI, Enser M, Wood JD, Richardson RI. 2006. Flavour perception of oxidation in beef. *Meat Science* **72,** 303–311.

Consortium. 1988. *Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching. Association Headquarters,* Savoy, IL.

Depenbusch BE, Coleman CM, Higgins JJ, Drouillard JS. 2009. Effects of increasing levels of dried corn distillers grains with solubles on growth performance, carcass characteristics, and meat qualityof yearling heifers. *Journal of Animal Science* **87,** 2653–2663.

Duckett SK, Wagne DG, Yates LD, Dolezal HG, May SG. 1993. Effects of time on feed on beef nutrient composition. *Journal of Animal Science* **71,** 2079–2088.

Dugan ME, Aldai RN, Kramer GK, Gibb DJ, Juarez M, McAllister TA. 2010. Feeding wheat dried distillers' grains with solubles improves beef trans and conjugated linoleic acid profiles. *Journal of Animal Science* **88,** 1842–1847.

Folch J, Lees M, Stanley GHS. 1957. A simple method for the isolation and purification of total lipids from animal tissue. *Journal of Biological Chemistry* **226,** 497–509.

Gunn PJ, Weaver A, Lemenager DRP, Gerrard DE, Claeys MC, Lake SL. 2009. Effects of dietary fat and crude protein on feedlot performance, carcass characteristics, and meat quality in finishing steers fed differing levels of dried distillers with solubles. *Journal of Animal Science* **87,** 2882–2890.

Ishida M, Takeda T, Saito T, Kano Y, Matsumoto T, Takahashi I. 1988. Fatty acid composition of the subcutaneous fat in Japanese Black steers during fattening. *The Japanese Journal of Zootechnical Science* **59,** 496–501.

Kimura N, Takahashi N. 2007. Characteristics and nutritional value of DDGS as a feed material. *Proceeding of Japanese Society for Animal Nutrition and Metabolism* **51,** 39–50.

Leupp JL, Lardy GP, Bauer ML, Karges KK, Gibson ML, Caton JS, Maddock RJ. 2009. Effects of distillers dried grains with solubles on growing and finishing steers intake, performance, carcass characteristics, and steak color and sensory attributes. *Journal of Animal Science* **87,** 4118–4124.

Loy TW, Klopfenstein TJ, Erickson GE, Macken CN, MacDonald JC. 2008. Effect of supplemental energy source and frequency on growing calf performance. *Journal of Animal Science* **86,** 3504–3510.

May SG, Sturdivant CA, Lunt DK, Miller RK, Smith SB. 1992. Comparison of sensory characteristics and fatty acid composition between Wagyu Crossbred and Angus steers. *Meat Science* **35,** 289–298.

Ministry of Agriculture, Forestry and Fisheries (MAFF). 2007. *Situation over the Animal Industry*. Ministry of Agriculture, Forestry and Fisheries, Tokyo, Japan.

Ministry of Health, Labour and Welfare. 1999. *Method of EISHIN No. 13, Analytical Methods for Nutrients on the Standards for Nutrition Labeling*. Ministry of Health, Labour and Welfare, Tokyo, Japan.

Mitsumoto M, Amold RN, Schaefer DM, Cassens RG. 1993. Dietary versus postmortem supplementation of vitamin E on pigment and lipid stability in ground beef. *Journal of Animal Science* **71,** 1812–1816.

Mitsumoto M, Cassens RG, Schaefer DM, Arnold RN, Scheller KK. 1991. Improvement of color and lipid stability in beef longissimus with dietary vitamin E and vitamin C dip treatment. *Journal of Food Science* **56,** 1489–1492.

National Agricultural Research Organization. 2001. *Standard Tables of Feed Composition in Japan*. Japan Livestock Industry Association. Tokyo, Japan.

Okumura T, Saito K, Sakuma H, Nade T, Nakagawa S, Fujita K, Kawamura T. 2007. Intramuscular fat deposition in principal muscles from twenty-four to thirty months of

age using identical twins of Japanese Black steers. *Journal of Animal Science* **85,** 1902–1907.
Roeber DL, Gill RK, DiCostanzo A. 2005. Meat quality responses to feeding distiller's grains to finishing Holstein steers. *Journal of Animal Science* **83,** 2455–2460.
Shibata N, Kinumaki T. 1979. An improvement of TBA procedure as the measure of the oxidative determination occurring in fish oils-? *Bulletin of the Japanese Society of Scientific Fisheries* **45,** 499–503.
Smith SB, Crouse JD. 1984. Relative contributions of acetate, lactate and glucose to lipogenesis in bovine intramuscular and subcutaneous adipose tissue. *Journal of Nutrition* **114,** 792–800.
Takahashi N, Kawai N, Kaneko T, Kimura N. 2008. Changes in the feed characteristics of DDGS during high temperature or humidification high temperature storage. *Nihon Chikusan Gakkaiho* **79,** 369–376. (In Japanese)
Tarladgis BG, Watts BM, Younathan MTY, Dugan LR Jr. 1960. A distillation method for quantitative determination of malonaldehyde in rancid foods. *Journal of the American Oil Chemists' Society* **37,** 44–50.
Ujiie T, Takeyama T, Kondo A, Hiroe R, Mori M. 1991. Rapid and reproducible determination of tocopherols in foods using high performance liquid chromatography with ethyl acetate/n-hexane extraction. *Vitamin (Japan)* **65,** 393–397.
Zerby HN, Belk KE, Sofos JN, McDowell LR, Smith GC. 1999. Case life of seven retail products from beef cattle supplemented with alpha-tocopheryl acetate. *Journal of Animal Science* **77,** 2458–2463.