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Effects of feeding modified distillers grains plus solubles on marbling attributes, proximate composition and fatty acid profile of beef

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Effects of feeding modified distillers grains plus solubles on marbling attributes, proximate composition and fatty acid profile of beef [1,2].

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ABSTRACT

Wet distillers grains contain approximately 65% moisture. A partially dried product (modified distillers grains plus solubles; MDGS) contains about 50% moisture. However, both have similar nutrient composition on a dry matter basis. The objective of this study was to investigate the effects of finishing diets varying in concentration of MDGS on marbling attributes, proximate composition, and fatty acid profile of beef. Yearling steers (n = 268) were randomly allotted to 36 pens which were assigned randomly to 0, 10, 20, 30, 40 and 50% MDGS (DM basis) and fed for 176 d prior harvest. Forty-eight h postmortem marbling score, marbling texture, and marbling distribution were assessed by a USDA grader and one ribeye slice (longissimus thoracis) 7 mm thick was collected from each carcass for proximate and fatty acid analysis. Treatments did not significantly alter marbling score or marbling distribution ($P \leq 0.05$). USDA Choice slices had coarser marbling texture when compared to USDA Select. Although dietary treatment affected marbling texture no consistent pattern was evident. Diets did not influence fat content, moisture, or ash of the ribeye ($P \geq 0.05$). For treatments 0, 10, 30, 40 and 50% there were positive linear relationships between marbling score and fat percentage in the ribeye ($P \leq 0.05$) and all slopes were similar ($P = 0.45$). Feeding MDGS linearly increased stearic, linoelaidic, linoleic, linolenic, PUFA and n-6 fatty acids. As levels of MDGS increased, linear decreases were observed in all n- 7 fatty acids and cubic relationships were detected for the 18:1 trans isomers (trans-6-8-Octadecenoic acid, 6-8t, elaidic acid, 9t, trans-10-Octadecenoic acid, 10t, and trans vaccenic, 11t). No effects were observed for saturated fatty acids containing 6 to 14 carbons. Feeding MDGS resulted in increased PUFA, *trans*, and Omega 6 fatty acids, minimal effects on marbling texture, and no effects on the relationship of marbling to intramuscular fat content relationship.

Key words: beef, modified distillers grains, fatty acids, marbling.

INRODUCTION

Over the last 10 years a significant increase in ethanol production in the U.S. has occurred, from 2.1 billion gallons in 2002 to 9 billion in 2008 (Renewable Fuels Association, 2009). Consequently, a greater supply of distillers byproduct has been available for cattle feeding. During milling, starch is removed from the grain and hydrolyzed to dextrin by an α -amylase enzyme. Dextrin is converted into glucose by glucoamylase sugar, and yeast species such as *Saccharomyces cerevisiae* convert glucose into ethanol and CO_2 (Davis, 2001). After fermentation, the whole stillage is centrifuged and coarser particles generate wet distillers grains (WDG) or dried distillers grains (DDG). When drying, the coarser fraction usually passes through a rotary dryer. The remaining liquid fraction is condensed, producing solubles (S). The solubles may be added back to WDG or DDG to form WDGS or DDGS, respectively (Stock et al., 2000). Modified distillers grains plus solubles (MDGS), are obtained through partial drying until achieving moisture levels of 50 to 54%.

The final concentration of protein and fat are increased in ethanol byproducts (Klopfenstein et al., 2007). Research conducted at the University of Nebraska has shown that feeding WDGS or DDGS combined with corn improves growth, reproduction, carcass traits, and cattle performance (Lodge et al., 1997; Martin et al., 2007; and Corrigan et al., 2009). However, little research has been conducted to quantify the effects of feeding MDGS on beef quality. Vander Pol et al. (2009) suggested that some fat in distillers grains may be protected from rumen biohydrogenation, which may increase the concentration of unsaturated fatty acid at the duodenum. These fatty acids may be absorbed and later deposited in the lean. Therefore, in this study we hypothesized that feeding MDGS could alter the fatty acid profile of beef. The aim of this work was to identify the effects of feeding MDGS on beef fatty acid percent.

MATERIAL AND METHODS

All procedures related to live animals for this study were approved by the Institutional Animal Care and Use Committee of the University of Nebraska-Lincoln.

Animal, Diets, and Sample Collection

Yearling (n = 268) Angus crossbred steers were randomly allocated to 36 pens, which were assigned randomly to six treatments (Table 1) containing high-moisture corn, dry-rolled corn, and different levels of MDGS (0, 10, 20, 30, 40, or 50% MDGS - DM basis). Although animals were fed by pen, the experimental unit in this work was the animal due to sampling conditions at the commercial plant. As levels of MDGS increased acroos the treatments, the ratio of dry-rolled corn and high moisture corn (1:1) decreased. Diets included 7.5% of alfalfa hay and 5% of supplement. Additionally, Rumensin (Elanco Animal Health) at 320 mg, Tylan (Elanco Animal Health) at 90 mg and thiamine at 150 mg per steer were supplemented daily. and implanted at day 1 and 67 with Synovex® Choice (Fort Dodge Animal Health). Steers were fed 176 d and implanted at day 1 and 67 with Synovex® Choice (Fort Dodge Animal Health) prior to slaughter and transferred to a commercial abattoir. Fourty-eight h postmortem, marbling attributes (score, texture, and distribution) were evaluated by a USDA beef carcass grading supervisor. After grading, a 7 mm-thick slice of the LM was collected at the $12^{th}/13^{th}$ rib region from each carcass to analyze the fatty acid profile and proximate composition. Ribeye slices were transferred under refrigeration to the University of Nebraska Meat Laboratory trimmed of subcutaneous fat and connective tissue, vaccum packaged and stored at -35°C. Prior to both analyses, samples were pulverized with liquid nitrogen (- 174°C) using a blender (Waring Commercial, model 51BL32, Torring, CT), and stored at -80°C until the fatty acid analysis and proximate analysis could be completed.

PROXIMATE AND FATTY ACID ANALYSES

Fatty acid profiles were analyzed according to Folch et al. (1957), Morrison and Smith (1964), and Metcalfe et al. (1966). Fatty acids were isolated from the lipid portion of the lean. One gram of pulverized sample was weighed out in a 40 mL conical tube and 5 mL of 2:1 chlorofrom:methanol (v/v) was added. The sample was homogenized for 5 s and allowed to stand for 1 h at room temperature. The homogenate was filtered through filter paper (Whatman #2) into a 13 x 150 mm screw tube, the final volume was brought to 10 mL with chlorofrom:methanol, and then homogenized for 5 s with 2 mL of 0.74% KCl. Samples were centrifuged at 1000 x g for 5 min, the top layer phase was aspirated, and tubes were dried under nitrogen at 60°C. After drying, samples were homogenized for 5 s with 0.5 mL of 0.5 M NaOH in methanol and heated for 5 min at 100°C. Following heating, 0.5 mL of BF_3 in 14% methanol was added into the tubes which were homogenized for 5 s and reheated at 100°C. Samples were homogenized with saturated salt solution (NaCl) and 1 mL of hexane for 5 s and centrifuged at 1000 x g for 5 min. After centrifuging, an aliquot of the top layer containing the fatty acid methyl esters was transferred to vials which were purged and capped with nitrogen prior to Gas Chromatography analysis (Hewlett-Packard Gas Chromatograph - Agilent Technologies, model 6890 series, CA, USA). Individual fatty acids were separated using a capillary column [Chrompack CP-Sil 88 (0,25 mm x 100 m)] and identified through retention time according to known standards (NuChek Prep (Elysian, MN) fatty acid methyl ester standards no. 68D, 79, 87 and 458). Temperature of the oven was set to increase from 140 to 220°C at 2°C/min and held at 220°C for 20 min. Simultaneously, injector and detector temperatures were maintained at 270 and 300°C, respectively, and compounds were carried by He at a flow rate of 1.0 mL/min.

Values of moisture and ash (%) were quantified by a LECO Thermogravimetric Analyzer (LECO Corporation, model 604-100-400, MI, USA). Moisture analysis was performed on N

atmosphere where the ramp rate was set at 6 °/m, ramp time at 17 min, start temperature at 25°C, and end temperature at 130°C. Ash analysis was performed on Oxygen atmosphere where the ramp rate was set at 20 d/m, ramp time at 30 min, start temperature at 130°C and end temperature at 600°C. For both moisture and ash analyses, flow rate, hold time, constant weight and constant weight time were set at high, 0 min, 0.05% and 9 min respectively. The crucible density was set at 3 and sample density at 1. Fat content was determined by ether extraction using the Soxhlet procedure (AOAC, 1990). Two grams of powdered samples were weighed out in a filter paper (Whatman #2) envelope and lipids were extracted using ether as the solvent.

Marbling, fatty acids and proximate analysis were analyzed as a complete randomized design where dietary treatment was the main effect. In this experiment, the animal was used as experimental unit. Linear and quadratic relationships were detected by response curves. Linear relationships between marbling and fat content were analyzed using the REG procedure and data were analyzed using the GLIMMIX procedure of SAS® (Version 9.2, Cary, N.C., 2007). When significance ($P \leq 0.05$) was indicated by ANOVA, means separations were performed using the LSMEANS and DIFF functions.

RESULTS AND DISCUSSION

MARBLING ATTRIBUTES AND PROXIMATE VALUES

Dietary treatments did not alter marbling score, marbling distribution, fat or ash (Table 2). A quadratic relationship was detected for moisture content. For marbling texture, there was a significant interaction between dietary treatment and USDA grade ($P = 0.02$). Carcasses graded USDA Choice had significantly coarser marbling texture than USDA Select carcasses from steers fed 0, 10, 20, 40, and 50% MDGS. Regarding treatments, although a significant interaction was observed, there was no consistent pattern to indicate an optimum level of MDGS

for marbling texture. Statistically, the individual *P* value of dietary treatment was 0.35 whereas for grade it was < 0.01. Thus, it appears that feeding MDGS had minimal effects on marbling texture due to its individual high *P* value. Except for 20% MDGS, all treatments showed significant linear relationships between marbling score and fat content ($P \leq 0.05$) (Table 3) and the test of common slopes revealed that all of them were similar (0.45) (Figure 1). Fat content of ribeyes vary from 7.43% to 8.68%. Considering that beef fat contains 8.5% of *trans* fat, important implications for human health and labeling may be an important issue since increased levels of *trans* fat per serving may be found.

As described previously, MDGS is very low in starch. When feeding grain, more propionate is produced in the rumen. The propionate can be converted to glucose and is correlated to marbling deposition (Smith and Crouse, 1984). Feedstuffs that are low in starch and contain more fiber are used in the rumen to yield more acetate, which is a precursor for subcutaneous fat deposition (Smith and Crouse, 1984). Modified wet distillers grains plus solubles contain more protein, fat, and fiber compared to corn (Klopfenstein et al., 2007). Therefore, we would expect significant differences in marbling through feeding MDGS. However, this study showed that levels up to 50% did not alter marbling attributes. Similar results were observed by Larson et al. (1993) and Lodge et al. (1997) when feeding wet distillers grains regarding quality grade. Vander Pol et al. (2009) showed that feeding distillers grains stimulated greater propionate production in the rumen than corn. They attribute this effect to the soluble. Corrigan et al. (2009) also showed that the inclusion of 40% of WDGS in diets containing dry rolled corn, high moisture corn, and steam-flaked corn led to higher levels of propionate and a lower acetate:propionate ratio in the rumen when compared to diets with no

addition of WDGS. Additionally, Russell (1998) showed that disitillers byproducts may change the ruminal pH, which influence the ratio of acetate:propionate.

Klopfenstein et al. (2008), summarizing different experiments, showed quadratic responses of ADG, G:F, and DMI as levels of WDGS increased in feedlot diets. Likewise, our experiment showed a quadratic relationship for fat content with optimal levels varying from 20 to 40%. Feeding levels above 45% may compromise HCW and ribeye area (Depenbush et al., 2009). It seems that optimal levels of distillers grains in diets vary from 20 to 40%.

FATTY ACIDS

Individual fatty acid percent are presented in Table 4. For 18:1 trans, we did not separate the isomers. Feeding MDGS did not affect percent of hexanoic (6:0), decanoic (10:0), lauric (12:0), myristic (14:0), isostearic (iso 18:0), homogamma linolenic (20:3, n-6) and arachidonic (20:4, n-6) fatty acids.

As levels of MDGS increased, a linear decrease of myristoleic (14:1, n- 5), pentadecanoic (15:0), palmitic (16:0), heptadecanoic (17:0), oleic (18:1, n-9), and docosapentaenoic (22:5, n-3) was observed (Table 4). A similar pattern was observed in all n-7 fatty acids. On the other hand, a linear increase in stearic (18:0), 18:1 *trans* isomers (trans-6-8-Octadecenoic acid, 6-8*t*, elaidic acid, 9*t*, trans-10-Octadecenoic acid, 10*t*, and trans vaccenic, 11t), linoleic (18:2, n-6), linolenic (18:3, n-3), nonadecanoic (19:0), and eicosanoic (20:0) was observed as levels of MDGS increased in the diets. In future studies, the identification of individual 18:1 *trans* fatty acid isomers may be useful to understand different potential health effects.

Similarly, CLA isomers (trans 7, cis 9-18:2 and cis 9, trans 11-18:2) increased linearly in the muscle as diets contained higher levels of byproduct.

Values of isopalmitic (iso 16:0) differed among the treatments ($P < 0.01$) and a quadratic trend was observed as MDGS levels increased ($P = 0.09$). For linoelaidic (18:2 *trans*), a quadratic relationship was detected due to a slight decrease of this fatty acid in beef from animals fed 50% MDGS. Although there was no difference among the treatments for CLA 18:2, *trans* 10, *cis* 12, a quadratic response in order of the increase of MDGS were observed. Looking at total *trans* percent, a cubic relationship was highly significant. However a quadratic response explained better the responses of total *trans* fatty acids to MDGS. Cubic relationships were observed for eicosenoic (20:1, n-9), and total SFA, however, treatments did not statistically differ in SFA. As levels of MDGS increased, percent of PUFA and n-6 fatty acids linearly increased. No effects of dietary treatment were observed in percent of n-3 fatty acids.

Triglycerides are biohydrogenated in the rumen by microbial lipases produced by bacteria releasing the fatty acids (Jenkins, 1993). Likely, the effects of MDGS inclusion in finishing diets on fatty acids percent in this work are due to the greater amount of fatty acids from this feedstuff that are biohydrogenated in the rumen (Vander Pol et al., 2009). It is known that fatty acids reaching the duodenum originate directly from diets and microbial transformation (Jenkins et al. 2008). After lipid hydrolysis, unsaturated fatty acids are converted to SFA through isomerization forming *trans* fatty acids intermediates including CLAs, which have their double bonds hydrogenated (Harfoot and Hazlewood, 1988). This explains the higher levels of total *trans* fatty acids in beef from animals fed 30 to 50% MDGS since the conversion of the linoleic at the beginning of the hydrogenation may be increased due to high digestibility of MDGS fat when compared to other fat sources. Additionally, Chin et al. (1992) affirmed that one of the most important CLA sources is lipid from ruminants. However in this work, very small percent of CLA were found in the muscle. This may be happened during methylation where the acidic

conditions could convert the CLA's to *trans* fatty acids or methoxy artifacts. However, during sample preparation all subcutaneous fat were removed from the sample. Jiang et al. (2010) showed that CLAs are found in greater percent in subcutaneous than intramuscular fat, therefore, lower values of CLAs in samples containing only lean tissue would be expected. As discussed previously, the fat digestibility of this feedstuff is higher than corn, generating larger percent of intermediates such as the CLA 18:2, *cis* 9, *trans* 11 during biohydrogenation. French et al. (2000) showed that the absorption of CLA from the gastrointestinal tract and amount of linoleic acid at the duodenum may affect the CLA absorption through changing the growth and activity of *Butyrivibrio fibrisolvenses*. This would explain a linear increase of this fatty acid in beef from animals fed 50% MDGS. Additionally, beef from cattle fed high fiber has higher CLA concentration when compared to corn (French et al., 2000). This is in agreement with feeding MDGS, which contain more fiber than corn. Linoleic and linolenic acids are the main UFA in ruminat diets (Woods and Fearon, 2009). During biohydrogenation, Wood et al. (1963) observed that after 48 h in the rumen, linoleic acid is converted to stearic (46%), oleic or 18:1 *trans* (33 to 50%), and 3 to 6% remained as linoleic. Additionally, Ward et al. (1964) reported that linolenic acid is rapidly hydrogenated in the rumen environment, generating linoleic, oleic and stearic acids. They reported that 93% of all intermediates linoleic acid are converted to stearic and a small accumulation of 18:1 *trans* can be found. In this work, all these three fatty acids increased linearly in lean tissue as levels of MDGS increased indicating that this conversion was optimized by feeding higher levels of MDGS. Vander Pol et al. (2009) found higher percent of of total 18:1 *trans*, oleic, and linoleic reaching the duodenum in WDGS fed cattle when compared to corn fed. The absorption of these fatty acids depends of the surface area of bile salt micelles, which may be enhanced by the presence of unsaturated fatty acids (Zinn et al., 2000). This explains the

linear increase in PUFA, n-6, and n-6: n-3 ratio as levels of MDGS increased in finishing diets. Lock et al. (2005) affirmed that the digestibility of fatty acids decreases as chain length and number of double bonds increase. In the present study, a linear decrease of docosapentaenoic acid was observed as MDGS levels increased.

Regarding the n-7 fatty acids, it appears that the higher digestibility of MDGS fat when compared to corn may have altered the biohydrogenation pathways decreasing the ability of the rumen bacteria to reduce these fatty acids. Consequently, the absorption and transportation of these fatty acids from the small intestine to the lean did not occur to the same extent as when animals are corn-fed.

Results and trends presented in this study regarding decanoic, lauric, myristic, pentadecanoic, palmitoleic, heptadecanoic, linoleic, CLA 18:2, *cis* 9, *trans* 11, total PUFA, and n-6: n-3 ratio are similar to results presented by Depenbush et al. (2009). Additionally, similar results regarding n-6 and omega 6:omega 3 were found by Gill et al. (2008) when comparing distillers grains to steam-flaked corn. Apparently, corn based distillers grains affect the fatty acid profile of beef differently compared to wheat-based distillers grains. Shand et al. (1998) found no effect on fatty acid profile in beef when feeding wheat-based distillers grains and wet brewers grains compared to corn, possibly due to the lower fat concentration of wheat (27%) when compared to corn (47%).

An increase of total *trans* fatty acids in beef from animals fed higher levels of MDGS was observed in this study. Grundy (1994) and Semma (2002) presented results where *trans* fatty acids and palmitic acid increased the low density lipoprotein (LDL) cholesterol and decreased the high density lipoprotein (HDL) cholesterol in human blood. Gould et al. (1998) showed that

LDL cholesterol may harm human health through the development of arthrosclerosis and subsequent coronary heart disease. However, Wahle et al. (2004) presented a series of studies reporting health benefits of CLAs such as anti-cancer, anti-atherosclerosis, anti-inflammatory, and anti-obesity properties, as well as capacity of enhancing antibody formation. The increase of stearic acid in beef as MDGS increased in the diets does not represent a potential risk for human health since this fatty acid does not or minimally affects total cholesterol (Kris-Etherton et al., 1993; Judd et al., 2002).

Jenschke et al. (2007), showed that there is a negative relationship between beef liver off-flavor and levels of *cis* vaccenic. Therefore, lower levels of this fatty acid may affect beef palatability.

In this study we observed higher percent of n-6 fatty acids, and n-6: n-3 ratio in beef from steers fed MDGS when compared to beef from corn-fed cattle. Simopoulos (2002) suggested that elevated levels of these fatty acids and elevated ratio may cause cardiovascular disease, cancer, inflammatory and autoimmune diseases. This could be minimized by higher levels of n-3, but no changes in these fatty acids were observed.

CONCLUSION

Feeding MDGS increased PUFA, total *trans*, n-6 fatty acids, n-6: n-3 ratio and decreased palmitic acid in beef. Athough the increase of PUFA may decrease lipid stability in meat, the change in fatty acid profile caused by feeding MDGS does not represent a risk to human health.

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Table 1. Dietary treatments composition (%DM basis).

	Treatments (% MDGS)					
Ingredients	**0**	**10**	**20**	**30**	**40**	**50**
Dry rolled corn	41.25	38.75	33.75	28.75	23.75	18.75
High moisture corn	41.25	38.75	33.75	28.75	23.75	18.75
MDGS	0	10	20	30	40	50
Alfalfa	7.5	7.5	7.5	7.5	7.5	7.5
Molasses	5	0	0	0	0	0
Mineral and vitamin supplement	5	5	5	5	5	5

Table 2. Marbling attributes and proximate values of ribeye slices (*Longissiumus thoracis*) from steers fed modified distillers grains plus solubles (MDGS, %).

	Dietary treatments (%MDGS – DM basis)						S.E.M.[1]	*P* - value	Contrasts[2]		
Attributes and prox. values	**0**	**10**	**20**	**30**	**40**	**50**			**Linear**	**Quadratic**	**Cubic**
Marbling score[3]	Slight^{93}	Slight^{93}	Small^{02}	Small^{01}	Slight^{95}	Slight^{93}	6.09	0.76	0.13	0.14	0.93
Marbling distribution[4]	1.12	1.20	1.13	1.17	1.22	1.21	0.06	0.71	0.12	0.83	0.76
Marbling texture[5] Choice	1.74^{Aa}	1.65^{Aa}	1.67^{Aa}	1.42^{B}	1.91^{Aa}	1.44^{Ba}	0.09	0.02*	0.41	0.91	0.14
Marbling texture[5] Select	1.11^{b}	1.23^{b}	1.18^{b}	1.24	1.08^{b}	1.15^{b}	0.09	0.02*	0.75	0.37	0.36
Fat, %	7.43	7.95	8.68	8.61	8.11	8.03	0.39	0.18	0.67	0.02	0.65
Moisture, %	71.58	71.09	70.52	70.38	70.91	71.19	0.30	0.06	0.74	<0.01	0.95
Ash, %	1.72	1.67	1.85	1.79	1.67	1.56	0.11	0.57	0.50	0.19	0.48

[1]Standard error of the mean.
[2]Linear, quadratic, and cubic responses to MDGS level.
[3]Slight = 300, and Small = 400.
[4]Even = 1, Uneven = 2.
[5]Fine =1, Medium = 2, Coarse = 3.
[A,B]Means in the same row having different superscripts are significant at $P = 0.02$ within marbling texture.
[a,b]Means in the same column having different superscripts are significant at $P = 0.02$ within marbling texture.
**P* - value for the interaction between dietary treatment and USDA quality grade.

Table 3. Linear relationships between marbling and fat content (%) ribeye slices (*Longissiumus thoracis*) from steers fed modified distillers grains plus solubles (MDGS, %).

Treatments (% MDGS, DM basis)	Marbling equations	P - value	R^2
0	306.47 + 12.49 fat	<0.01	0.18
10	258.48 + 17.01 fat	<0.01	0.30
20	348.57 + 8.39 fat	0.10	0.07
30	310.60 + 9.51 fat	<0.01	0.19
40	293.00 + 12.26 fat	<0.01	0.21
50	326.45 + 6.86 fat	0.04	0.10

Table 4. Weight percentage of fatty acids[1] of ribeye slices (*Longissimus thoracis*) from steers fed modified distillers grains plus solubles (MDGS, %).

	Dietary treatments (%MDGS – DM basis)						S.E.M.[2]	*P*- value	Contrasts[3]		
Fatty Acid	**0**	**10**	**20**	**30**	**40**	**50**			**Linear**	**Quadratic**	**Cubic**
6:0 - hexanoic	0.22	0.22	0.18	0.20	0.20	0.21	0.02	0.48	0.95	0.34	0.84
10:0 - decanoic	0.005	0.01	0.01	0.02	0.02	0.01	0.004	0.15	0.16	0.26	0.99
12:0 - lauric	0.02	0.02	0.02	0.03	0.03	0.02	0.006	0.84	0.73	0.87	0.32
14:0 - myristic	3.34	3.36	3.25	3.21	3.20	3.15	0.07	0.18	<0.01	0.99	0.83
14:1(n- 5) - myristoleic	0.93^{a}	0.83^{b}	0.77^{bc}	0.77^{bc}	0.75^{bc}	0.71^{c}	0.03	<0.01	<0.01	0.04	0.19
15:0 - pentadecanoic	0.55^{ab}	0.57^{a}	0.54^{ab}	0.51^{bc}	0.52^{bc}	0.49^{c}	0.01	<0.01	<0.01	0.64	0.37
iso16:0 - isopalmitic	0.54^{ab}	0.55^{a}	0.42^{c}	0.44^{bc}	0.43^{c}	0.49^{abc}	0.04	<0.01	0.22	0.09	0.42
16:0 - palmitic	26.00^{a}	25.46^{b}	25.15^{b}	24.38^{c}	24.39^{c}	24.45^{c}	0.18	<0.01	<0.01	0.02	0.27
16:1(n- 7) - palmitoleic	3.37^{a}	3.12^{b}	2.82^{c}	2.76^{cd}	2.56^{de}	2.45^{e}	0.07	<0.01	<0.01	0.07	0.58
17:0 - heptadecanoic	1.45^{a}	1.48^{a}	1.44^{a}	1.29^{b}	1.28^{b}	1.25^{b}	0.03	<0.01	<0.01	0.30	0.01
17:1(n- 7) - heptadecenoic	1.16^{a}	1.10^{a}	0.98^{b}	0.89^{c}	0.82^{dc}	0.78^{d}	0.02	<0.01	<0.01	0.28	0.31
Iso18:0 - isostearic	0.30	0.34	0.29	0.32	0.32	0.35	0.02	0.46	0.06	0.55	0.45
18:0 - stearic	12.55^{d}	13.44^{c}	13.92^{cb}	14.21^{b}	14.34^{b}	15.10^{a}	0.25	<0.01	<0.01	0.31	0.13
18:1 *trans*[4]	4.43^{d}	4.96^{d}	6.26^{c}	6.61^{c}	8.39^{a}	7.48^{b}	0.30	<0.01	<0.01	0.04	<0.01
18:1(n-9) - oleic	36.45^{a}	35.76^{ab}	34.15^{bc}	34.01^{c}	32.76^{c}	32.86^{c}	0.63	<0.01	<0.01	0.25	0.62
18:1(n- 7) - *cis* vaccenic	2.33^{a}	1.95^{b}	1.76^{bc}	1.59^{c}	1.59^{c}	1.33^{d}	0.09	<0.01	<0.01	0.12	0.11
18:2 *trans* - linoelaidic	0.06^{c}	0.07^{bc}	0.10^{a}	0.11^{a}	0.12^{a}	0.09^{ab}	0.01	<0.01	<0.01	0.01	0.16
18:2(n-6) - linoleic	3.13^{d}	3.92^{c}	4.29^{c}	4.85^{b}	5.07^{b}	5.64^{a}	0.15	<0.01	<0.01	0.28	0.33
CLA 18:2, *cis* 9, *trans* 11	0.000^{c}	0.000^{c}	0.004^{c}	0.01^{c}	0.02^{b}	0.04^{a}	0.005	<0.01	<0.01	0.55	0.68
CLA 18:2, *trans* 10, *cis* 12	0.000	0.002	0.003	0.006	0.007	0.004	0.002	0.26	0.03	0.002	0.59
18:3(n-3) - linolenic	0.17^{b}	0.19^{ab}	0.20^{a}	0.20^{ab}	0.21^{a}	0.22^{a}	0.01	0.02	<0.01	0.51	0.26
19:0 - nonadecanoic	0.005^{b}	0.003^{b}	0.02^{ab}	0.03^{a}	0.03^{a}	0.03^{a}	0.006	<0.01	<0.01	0.92	0.56
20:0 - eicosanoic	0.02^{b}	0.04^{ab}	0.06^{a}	0.05^{ab}	0.06^{a}	0.06^{a}	0.009	0.02	0.02	0.08	0.73
20:1(n-9) - eicosenoic	0.50^{a}	0.44^{b}	0.50^{a}	0.52^{a}	0.51^{a}	0.48^{ab}	0.02	0.05	0.62	0.36	0.02
20:3(n-6) - homogamma linolenic	0.13	0.13	0.13	0.15	0.13	0.15	0.02	0.74	0.29	0.99	0.82
20:4(n-6) - arachidonic	0.53	0.60	0.48	0.50	0.51	0.58	0.04	0.23	0.45	0.16	0.14
22:5(n-3) - docosapentaenoic	0.05^{a}	0.04^{ab}	0.02^{bc}	0.02^{bc}	0.01^{c}	0.01^{c}	0.009	<0.01	<0.01	0.10	0.90

[1]Weight percentage values are relative percent of all peaks observed by Gas Chromatography.
[2]Standard error of the mean.
[3]Linear, quadratic, and cubic responses to MDGS level.
[4] Includes *trans*-6-8-Octadecenoic acid, 6-8*t*, elaidic acid, 9*t*, *trans*-10-Octadecenoic acid, 10*t*, and *trans* vaccenic, 11t.
[a,b,c,d]Means in the same row having different superscripts are significant at $P \leq 0.05$.

Table 5. Weight percentage of fatty acids[1] groups of ribeye slices (*Longissimus thoracis*) from steers fed modified distillers grains plus solubles (MDGS, %).

	Dietary treatments (%MDGS – DM basis)						S.E.M.[2]	*P* - value	Contrasts[3]		
Fatty Acids	**0**	**10**	**20**	**30**	**40**	**50**			**Linear**	**Quadratic**	**Cubic**
SFA	45.02	45.51	45.33	44.71	44.84	45.63	0.31	0.20	0.68	0.47	0.02
PUFA	4.08^{d}	4.95^{c}	5.24^{c}	5.85^{b}	6.08^{b}	6.71^{a}	0.18	<0.01	<0.01	0.46	0.27
Total *trans*[4]	4.49^{d}	5.03^{d}	6.37^{c}	6.73^{c}	8.53^{a}	7.59^{b}	0.30	<0.01	<0.01	0.03	<0.01
n-3	0.22	0.23	0.23	0.22	0.23	0.23	0.02	0.99	0.90	0.71	0.36
n-6	3.80^{d}	4.65^{c}	4.90^{c}	5.50^{b}	5.72^{b}	6.37^{a}	0.18	<0.01	<0.01	0.55	0.28
n-6: n-3	16.07^{d}	19.20^{c}	21.08^{bc}	22.89^{ab}	23.22^{ab}	25.03^{a}	0.85	<0.01	<0.01	0.06	0.59

[1]Weight percentage values are relative percent of all peaks observed by Gas Chromatography.
[2]Standard error of the mean.
[3]Linear, quadratic, and cubic responses to MWDGS level.
[4]Total trans fats includes *trans*-6-8-Octadecenoic acid, 6-8*t*, elaidic acid, 9*t*, *trans*-10-Octadecenoic acid, 10*t*, *trans* vaccenic, 11t, and the 18:2 trans isomers.
[a,b,c,d]Means in the same row having different superscripts are significant at $P \leq 0.05$.

Figure Caption

Figure 1. Relationship between intramuscular fat and marbling score from steers fed modified distillers grains plus solubles (MDGS, %).

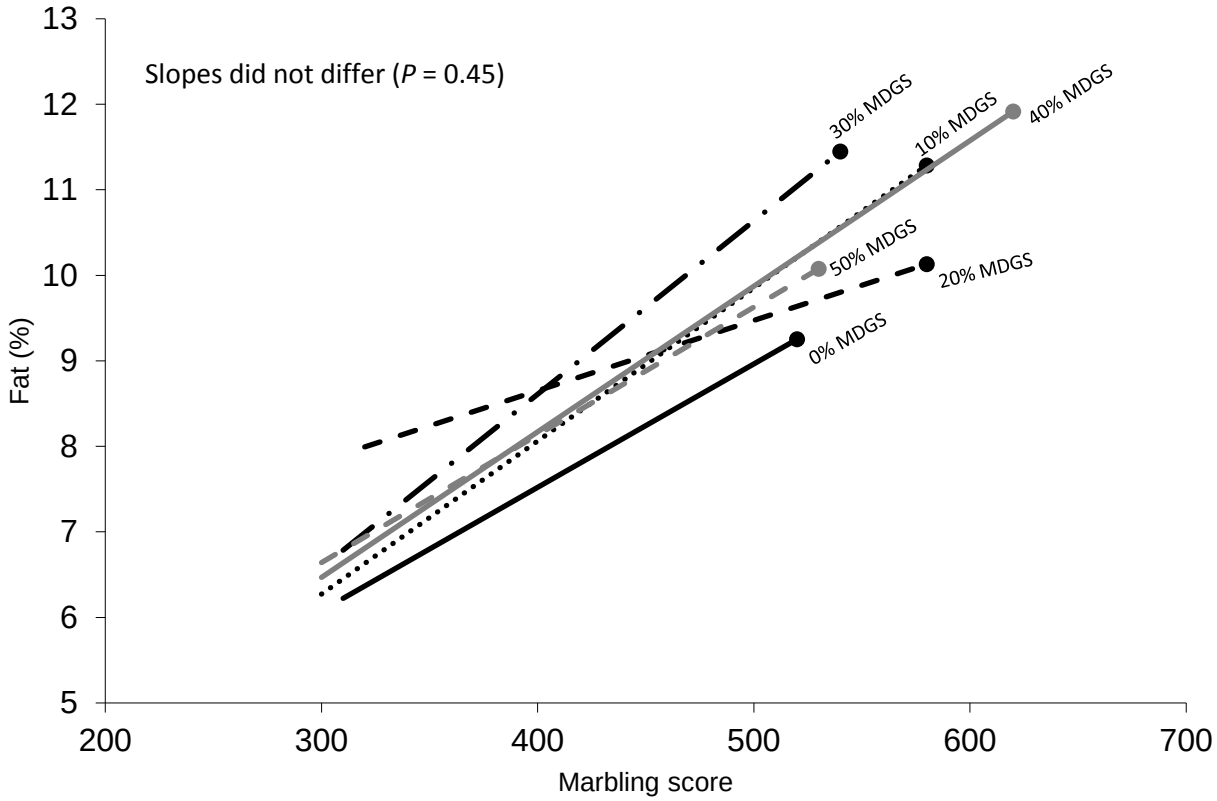

Figure 1