Effect of dried distillers' grains from wheat on diet digestibility and performance of feedlot cattle

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Gibb, D. J., Hao, X. and McAllister, T. A. 2008. **Effect of dried distillers' grains from wheat on diet digestibility and performance in feedlot cattle**. Can. J. Anim. Sci. **88**: 659–665. In a 55-d backgrounding period, 120 British cross heifers (312 ± 20 kg) received diets containing 55% barley silage, 5% supplement and 0 (n = 24), 20 (n = 24), or 40% (n = 72) wheat distillers' dried grains with solubles (DDGS). The remainder of the diet was steam-rolled barley. Replacing half (20%) or all (40%) of the barley with DDGS did not affect dry matter intake (DMI) (P = 0.61), average daily gain (ADG) (P = 0.86), or gain:feed (P = 0.94), indicating the energy content of DDGS is similar to that of barley when included in backgrounding diets. During a 133-d finishing period, DDGS were included at 0, 20, 40, or 60% of diet dry matter (DM) or at 60% plus additional calcium, provided as 1% limestone (n = 24). Additional calcium did not (P > 0.1) affect DMI, ADG, or gain:feed. Increasing levels of DDGS linearly increased (P = 0.001) DMI and reduced (P = 0.04) gain:feed and diet NEg content (P = 0.001), but had no effect on ADG (P = 0.20). Feeding 60% DDGS reduced (P < 0.01) DM digestibility as compared with the control. Wheat DDGS has similar feeding value as barley when included at 20% of diet DM, but digestibility and energy content decline with higher levels of inclusion.

Key words: Beef, digestibility, distillers' dried grains, wheat

Gibb, D. J., Hao, X. et McAllister, T. A. 2008. **Incidence des drèches sèches de distillerie de blé sur la digestibilité de la ration et le rendement des bovins de boucherie**. Can. J. Anim. Sci. **88**: 659–665. Durant une période de semi-finition de 55 jours, des génisses hybrides British (312 ± 20 kg) ont reçu une ration contenant 55 % d'ensilage d'orge, 5 % de supplément et soit 0 (n = 24), 20 (n = 24) ou 40 % de drèches sèches de distillerie de blé avec résidus solubles (DDGS; n = 72). Le reste de la ration était constitué de flocons d'orge. Remplacer la moitié (20 %) ou la totalité (40 %) de l'orge par des DDGS n'affecte pas l'ingestion de matière sèche (P = 0,61), le gain quotidien moyen (P = 0,86) ni le ratio gain/aliment (P = 0,94), signe que les DDGS renferment autant d'énergie que l'orge quand on s'en sert pour la semi-finition. Lors d'une période de finition de 133 jours, les chercheurs ont remplacé 0 (n = 24), 20 (n = 24), 40 (n = 24) ou 60 % de la matière sèche de la ration (n = 24) par des DDGS. Une cinquième ration, contenant un supplément de calcium (1 % de chaux) et 60 % de DDGS (n = 24) a aussi été évaluée. Le calcium supplémentaire n'affecte pas (P > 0,1) l'ingestion de matière sèche, le gain quotidien moyen ni le ratio gain/aliment. Augmenter la concentration de DDGS entraîne une hausse linéaire (P = 0,001) de l'ingestion de matière sèche et diminue (P = 0,04) le ratio gain/aliment ainsi que la concentration de NEg dans la ration (P = 0,001), mais n'a aucun effet sur le gain quotidien moyen (P = 0,20). Une proportion de 60 % de DDGS dans la ration réduit (P < 0,01) la digestibilité de la matière sèche, comparativement à la ration témoin. Les DDGS de blé ont la même valeur alimentaire que l'orge quand elles constituent 20 % de la matière sèche de la ration, mais la digestibilité et la teneur en énergie de cette dernière diminuent à mesure que cette proportion augmente.

Mots clés: Bœuf, digestibilité, drèches sèches de distillerie, blé

With rising fuel prices and increased government incentives, there are now more than 1.5 billion liters of fuel ethanol produced in Canada each year (Canadian Renewable Fuels Association 2007), with one-third of this amount arising from the fermentation of wheat. Starch accounts for approximately 70% of the weight of wheat. In ethanol production, this starch is removed through fermentation by yeast to produce ethanol, resulting in approximately a threefold concentration of non-starch components in the remaining residue. Ethanol is removed from the fermented slurry through distillation. The resulting mash is centrifuged to separate the coarse grains from the solubles. The solubles can be condensed through evaporation resulting in a syrup of about 30% DM. The coarse grains can be fed to livestock or dehydrated to produce dried distillers' grains (DDG). If the condensed solubles are added back to the distillers' grains before dehydration, the resulting product is known as dried distillers' grains with solubles (DDGS).

Grains are often fed to feedlot cattle as they are typically the cheapest source of energy. Due to its high

Abbreviations: **ADG**, average daily gain; **DM**, dry matter; **DMI**, dry matter intake; **DDGS**, dried distillers' grains with solubles; **20%**, diet dry matter contained 20% DDGS; **40%**, diet dry matter contained 40% DDGS; **60%**, diet dry matter contained 60% DDGS; **60% + Ca**, diet dry matter contained 60% DDGS and 1% limestone digestibility, starch is generally assumed to be the primary source of energy and a direct indicator of the value of cereal grains. However, feeding trials with wet corn distillers' grains indicate the energy value is at least as high as in the complete grain (Klopfenstein et al. 2008), but that efficiency of utilization may decline with increasing levels (Larson et al. 1993).

Wheat is similar to corn in most nutrients, but has about half the oil content and considerably more protein [National Research Council (NRC) 1996]. As a result, wheat DDGS is typically higher in protein (~40 vs. ~30%) and considerably lower in oil (~5 vs. >10%) than corn DDGS. Grains are relatively high in P but low in Ca, so finishing diets are typically supplemented with Ca to meet requirements. Low Ca:P ratios can cause urinary calculi in sheep (NRC 1980) and can cause metabolic and other problems in cattle (Kincaid 1988). As a result, Ca:P ratios in feedlot diets are typically managed to provide a minimum ratio of at least 1.5:1. Compared with grains, P content in DDGS is approximately three times higher as a result of the fermentation of starch. Therefore, addition of extra Ca to the diet may be beneficial in maintaining proper Ca:P ratios when elevated levels of DDGS are fed.

When included at more than 5% in barley-based diets, wheat DDGS provide more protein than feedlot cattle require (>13.5%). Urea must be synthesized to excrete the N from feeding excess protein. Urea synthesis has a metabolic cost (Mathews and van Holde 1990), so feeding elevated levels of protein may affect efficiency of energy use.

The current trial was conducted to determine how increasing levels of wheat DDGS in feedlot diets influence performance (DMI, ADG and gain:feed) and carcass traits, and to determine if extra dietary Ca is beneficial when included in DDGS diets. The effect of elevated levels of DDGS on diet digestibility was also determined.

MATERIALS AND METHODS

All cattle used in this study were cared for in accordance with guidelines set by the Canadian Council on Animal Care (CCAC 1993). One hundred twenty large-framed British cross heifers (312 ± 20 kg) were housed individually in an enclosed shelter. Each pen (1.85 × 6.15 m) included a feed bunk and water trough at one end and an access gate at the other end. Adjacent pens were separated by plank fencing. Cattle were weighed (without withdrawal of feed or water) prior to feeding on 2 consecutive days to obtain initial (days 0, 1) and final (days 187, 188) weights. Based on weights obtained on day 0, heifers were sorted by weight for assignment to one of five treatment diets ($n = 24$). Weights were also obtained on days 56 and 112 of the experiment. Shrunk weights (full weight × 96%) were used in calculating performance. During processing on day 0, cattle were ear-tagged and given dectomax (Pfizer Animal Health, Kirkland, QC), an eight-way clostridial vaccine (Tasvax; Intervet, Whitby, ON), and an IBR, PI_3 and *Haemophilus somnus* vaccine (Resvac 4; Pfizer Animal Health). Cattle were provided ad libitum access to feed and water throughout the study. Fresh feed was mixed and delivered daily using a Calan Data Ranger (American Calan, Northwood, NH).

Dietary Treatments

Experimental diets (Table 1) were prepared using the ingredients described in Table 2. Control diets contained barley (steam-rolled) at levels typical of the western Canadian feedlot industry. During the backgrounding period (55 d), the control diet contained 40% (DM basis) steam-rolled barley grain. Distillers' grains were included in growing and transition diets up to a maximum of the barley level in the control diet. For example, during the backgrounding period, diets included 0 ($n = 24$), 20 ($n = 24$), and 40% ($n = 72$) DDGS. Following backgrounding, grain content (barley + DDGS) in the diet was increased using four transition diets, each fed for 5 d, in order to adapt cattle to an 85% grain finishing diet. Levels of DDGS (DM basis) fed during the finishing period were: 0 ($n = 24$), 20 ($n = 24$), 40 ($n = 24$), and 60% ($n = 24$), plus 60% with extra calcium (60% + Ca; $n = 24$). Cattle receiving the 60% DDGS diets had received 40% during the backgrounding period. The extra calcium provided in the fifth treatment was supplied from limestone which was added directly (1% of DM) to the finishing diet. All diets contained 5% supplement, which provided calcium, trace minerals and vitamins. The supplement also contained monensin so as to provide 25 mg kg^{-1} in the complete diet. Protein (25%) was included in the supplement to ensure adequate (>13%) levels in the control diet.

Sample Collection and Analyses

Barley and silage samples were sampled weekly and composited monthly for analysis. A sample of DDGS was obtained from each load received ($n = 5$) from the ethanol plant. Samples were analyzed for DM by drying in a forced-air oven at 55°C for 48 h. Dried feed samples were ground to pass through a 1-mm screen and analyzed for NDF and ADF with α-amylase (Van Soest et al. 1991). Protein content was determined using a Carlo Erba® NA 1500 Carbon-Nitrogen elemental analyzer (Carlo Erba Strumentazione, Rodano, Milan, Italy). Mineral levels were determined by inductively coupled plasma optical emission spectrometry. Lipids were extracted with ether (AOAC 1990) to determine oil content.

Orts were collected and weighed weekly. Dry matter intake was calculated as (feed delivered – orts collected) × %DM of the diet fed. Average daily gain,

Table 1. Diet formulas (DM basis) and number of observations during backgrounding and finishing periods

	0%	20%	40%	60%	60% + Ca
Backgrounding diets[z]					
Barley silage	55	55	55	–	–
DDGS	0	20	40	–	–
Barley	40	20	0	–	–
Supplement[x]	5	5	5	–	–
No. of observations	24	24	72	–	–
Finishing diets[y]					
Barley silage	10	10	10	10	10
DDGS	0	20	40	60	60
Barley	85	65	45	25	24
Supplement[x]	5	5	5	5	5
Limestone	0	0	0	0	1
No. of observations	24	24	24	24	24
Analysis (DM basis)					
Dry matter (%)	74.70	75.70	76.71	77.80	77.90
Protein (%)	13.6	20.0	26.4	32.7	32.9
Protein from NPN (%)	0.50	0.50	0.50	0.50	0.50
Calcium (%)	0.77	0.79	0.81	0.83	1.19
Phosphorus (%)	0.38	0.50	0.61	0.73	0.73
Calcium:phosphorus	2.02	1.59	1.32	1.14	1.64
Oil (%)	1.90	2.50	3.10	3.70	3.60

[z]Backgrounding diets fed from day 1 to day 55.
[y]Cattle were adapted to finishing diets by sequentially reducing silage content through four transition diets that were each fed for 5 d. Finishing diets were fed a total of 118 d.
[x]Supplement contained 108.5 mg kg^{-1} Cu, 425.9 mg kg^{-1} Zn, 254.0 mg kg^{-1} Mn, 5.3 mg kg^{-1} I, 1.1 mg kg^{-1} Co, 3.3 mg kg^{-1} Se, 25.4 KIU kg^{-1} vitamin A, 2.5 KIU kg^{-1} vitamin D, 254.4 IU kg^{-1} vitamin E.

DMI, and gain:feed were determined in each period for which animal weights were obtained.

Net energy for maintenance (NEm) content of each diet was calculated from animal weights, DMI and ADG as described by Zinn et al. (2002) using the retained energy formula for a medium-frame steer calf [$0.0557 \times (\text{average weight} \times 478/\text{mature weight})^{0.75} \times \text{ADG}^{1.119}$; NRC 1996] with a mature weight of 600 kg. The NEm content of DDGS in each diet was calculated as (NEm of test diet – NEm of control diet)/% DDGS in test diet + NEm of barley grain (2.06). For comparison with corn distillers' research, NEm was converted to NEg as described by Zinn et al. (2002; $\text{NEg} = \text{NEm} \times 0.877 - 0.41$).

Diet Digestibility

The total tract DM digestibilities of the 0, 60%, and 60% + Ca diets were determined using chromic oxide as an external marker as outlined by Beauchemin and McGinn (2006). In summary, 10 g of marker providing 2 g of Cr was top dressed onto the rations of five of the heifers fed the 0, 60 or 60% + Ca diets from day 172 to day 182. Fecal samples (about 100 g wet weight) were extracted from the rectum daily at 0900 and 1530 from

Table 2. Analysis (DM basis) of ingredients used in diet formulation

	Barley grain ($n = 3$)	Barley silage ($n = 3$)	DDGS[z] ($n = 5$)
Dry matter (% as fed)	89.1 ± 0.83	42.8 ± 1.5	91.6 ± 1.40
Crude protein (%)	13.6 ± 0.55	12.4 ± 0.28	45.8 ± 1.26
NDF (%)	22.2 ± 0.46	49.7 ± 1.65	28.9 ± 1.23
ADF (%)	6.4 ± 0.23	33.0 ± 1.45	19.5 ± 2.13
Ether extract (%)	1.72 ± 0.04	2.13 ± 0.09	4.6 ± 0.07
ADIN (% of N)	14.9 ± 6.08	9.7 ± 1.43	7.41 ± 6.44
Calcium (%)	0.05 ± 0.00	0.38 ± 0.03	0.15 ± 0.01
Phosphorus (%)	0.38 ± 0.02	0.30 ± 0.00	1.07 ± 0.05
Magnesium (%)	0.15 ± 0.01	0.24 ± 0.02	0.42 ± 0.01
Sodium (%)	0.02 ± 0.00	0.58 ± 0.12	0.30 ± 0.09
Potassium (%)	0.47 ± 0.04	2.54 ± 0.16	1.10 ± 0.04
Sulfur (%)	0.16 ± 0.01	0.30 ± 0.04	0.48 ± 0.02

[z]Wheat-based dried distillers' grains with solubles.

day 177 to day 182. Samples were composited by animal and immediately frozen (−20°C). Samples were later dried at 55°C for 48 h in a forced-air oven, ground through a 1-mm screen and analyzed for DM content. An additional fecal sample was collected from each animal prior to feeding the marker to correct for initial Cr excretion. Digestibility was calculated based on concentrations of Cr fed/concentrations of Cr excreted using the ratio technique.

Carcass Measurement

At harvest, carcass characteristics including warm carcass weight (with internal fat removed), dressing percentage, back fat thickness, and quality grade were obtained. Liver abscesses were ranked based on severity (Brown et al. 1975) using a scale from 0 (no abscesses) to 3 (more than four small abscesses or at least one abscess greater than 2.5 cm in diameter).

Statistical Analysis

Individual animal was the experimental unit with treatment as the only class variable. The MIXED procedure of SAS software (SAS Institute, Inc.) was used to compare DMI, ADG, and gain:feed using the residual error as the error term. Orthogonal contrasts were used to compare linear and quadratic effects of including 0, 20, 40, or 60% DDGS. Linear and quadratic contrasts did not consider the 60%+Ca diet. Diet digestibility of the 0, 60, and 60%+Ca diets were also compared using orthogonal contrasts.

RESULTS AND DISCUSSION

Chemical analysis of wheat DDGS was comparable with previous research (Ojowi et al. 1997; Mustafa et al. 2000; Widyaratne and Zilstra 2007; Table 2). This analysis would be unique to wheat DDGS, as composition can differ substantially among grains (Lodge et al. 1997; Al-Suwaiegh et al. 2002) and between the wet and dry product (Ham et al. 1994; Lodge et al. 1997). In the finishing diets, protein and P increased from 14.0 to 32.9% and from 0.38 to 0.73%, respectively, with inclusion of 60% DDGS in the diet. Calcium:phosphorus ratio of the finishing diet ranged from 2:1 in the control diet down to 1.1:1 in the 60% DDGS diet. Extra calcium in the 60%+Ca diet increased the Ca:P ratio to over 1.6:1, but numerically reduced DMI ($P = 0.49$), ADG ($P = 0.11$) and gain:feed ($P = 0.26$).

Using increasing levels of P in diets containing 0.30 or 0.70% calcium, Erickson et al. (1999) found no interactions between Ca and P levels on performance as Ca:P ratios declined from 5:1 to 1:1. Performance was not affected with Ca:P ratios as low as 1:1 in the trials of Ricketts et al. (1970). When ratios ranging from 0.1:1 to 14:1 were investigated, Wise et al. (1963) determined that optimum ratios were between 1:1 and 7:1. The results of the current research support NRC (1996) conclusions that Ca:P ratios have been overemphasized in the past. The extra limestone in the 60%+Ca treatment was provided to increase Ca:P ratios in a diet that already contained adequate Ca levels for growth (NRC 1996). Dietary calcium in excess of requirements has improved gain or feed efficiency in some trials (Huntington 1983; Brink et al. 1984; Bock et al. 1991). However, excess levels of limestone have reduced DMI and even gains in other trials (Russel et al. 1980; Hironaka 1988; Erickson et al. 1999), possibly through reduced OM digestion resulting from increased rumen fluid dilution rates (Goetsch and Owens 1985).

Dry matter digestibility declined ($P = 0.03$) from 76.4% in the control diet to 68.9% in the 60% diet. The 60%+Ca diet was also less digestible (65.8%; $P = 0.005$) than the control diet, but there was no difference ($P = 0.34$) between the 60% and 60%+Ca diets. Peter et al. (2000) observed a trend of reduced DM digestibility when DDGS from corn was included at 20% of DM. Total tract digestibility of diets containing 40% wheat DDGS was 9% lower than was reported for a wheat-based diet in growing pigs (Widyaratne and Zijlstra 2007). Reduced digestibility with dried compared with wet distillers' grain has been observed in some (Lodge et al. 1997) but not all trials (Firkins et al. 1985).

Performance

Replacing half or all of the barley with DDGS in the backgrounding diet did not affect DMI (6.71 kg d^{-1}; $P = 0.90$), ADG (0.93 kg d^{-1}; $P = 0.84$), or gain:feed (0.132; $P = 0.77$), which indicates that the energy value of DDGS is similar to barley in these diets.

During the finishing period, there was a linear ($P = 0.001$) increase in DMI with increasing levels of DDGS, which resulted in higher ($P = 0.02$) DMI for cattle fed DDGS. Dry matter intake of high-grain finishing diets typically increases with increasing NDF levels (Galyean and Defoor 2002) and/or decreasing energy content (NRC 1996). Factors known to suppress DMI, such as the production of specific VFA (Baile 1971; Baile and Forbes 1974) and pH reductions (Fulton et al. 1979), may also have been moderated, when DDGS was substituted for the rapidly fermentable barley grain. Increasing levels of corn DDGS from 0 up to 40 (Buckner et al. 2007) or 75% (Gordon et al. 2002) did not affect DMI in corn-based diets. With corn distillers' grains, feeding the dried product has resulted in higher intake, but lower energy content compared with the wet product (Ham et al. 1994).

Increasing DMI with no difference in ADG ($P = 0.20$) resulted in a linear ($P = 0.04$) decline in gain:feed with increasing levels of wheat DDGS. Gain:feed has also been shown to decline linearly with increasing levels of corn DDGS in some (Gordon et al. 2002) but not all (Buckner et al. 2007) studies. Vander Pol et al. (2005) summarized feeding trials that evaluated performance of cattle fed corn distillers' grains and concluded that the energy content of wet distillers' grains was higher than that of dry-rolled corn, but that this difference declined with increasing levels of distillers' grains in the diet.

Consistent with the reduced digestibility and linear increase in DMI, dietary energy content (NEg, MCal kg^{-1}) declined linearly ($P = 0.05$) with increasing levels of DDGS (Table 3). Calculated NEg values were converted to TDN (%) using the NRC formula, as documented by Owens et al. (1997). Based on NEg values, TDN content decreased from 70 to 67% (4.3% reduction). Actual DM digestibility decreased from 76.4 to 68.9% (9.8% reduction). In other words, reduction in NEg content was less than expected based on digestibility. On the basis of animal performance and DM digestibility, the energetic cost of N excretion was not evident.

Based on NEg content of the diet, NEg of DDGS ranged from a high of 1.36 when fed at 20% to a low of 1.26 MCal kg^{-1} when fed at 60% of the diet; or 97 and 90%, respectively, the energy content of barley. Similarly, Erickson and Klopfenstein (2007) documented that wet distillers' grains from corn provided more energy when fed at 10% than at 40% of diet DM. However, feed efficiency linearly improved when wet corn distillers' grains were included at 0, 25, or 50% of the diet in the trial of Firkins et al. (1985). Based on animal performance, Al-Suwaiegh et al. (2002) calculated the NEg content of wet corn distillers' grains to be 33.3% greater than that of dry-rolled corn. On the basis of oil concentration in corn distillers' grains, those researchers determined that 42% of the improved NEg was due to the increased lipid content of corn distillers' grains. Oil content of corn grain and the distillers' product is approximately twice as high as in wheat.

Carcass Traits

Feeding DDGS did not affect carcass weight (342 kg; $P = 0.32$), dressing percentage (58.6%; $P = 0.65$), or ribeye area (91.9 cm^2; $P = 0.50$; Table 4). Feeding DDGS resulted in back fat thickness being greater (quadratic increase; $P = 0.04$) in cattle fed 20% DDGS (14.06 mm) than in those fed 0% (9.72 mm; $P = 0.0002$), 60% (11.67 mm; $P = 0.03$), or 60% + Ca (11.30 mm; $P = 0.01$). At modest rates of gain, carcass fat usually increases with increased growth rates (Owens et al. 1995). Cattle fed DDGS had more (12.58 vs. 9.72 mm; $P = 0.003$) back fat than did cattle that were not fed DDGS. Back fat has been reported to decrease with increasing levels of corn DDGS in the diet (Gordon et al. 2002). Wet or dried sorghum distillers' grains did not affect back fat thickness in a study conducted by Lodge et al. (1997). Increased levels of intermuscular fat were observed when 4.7% wet wheat distillers' grains were fed to feedlot cattle by Ojowi et al. (1997).

Increased levels of back fat coincided with a trend ($P = 0.10$) toward reduced meat yield for cattle fed DDGS (57.45 vs. 60.41%). No differences were observed between treatments in incidents of total ($P = 0.36$) or severely ($P = 0.44$) abscessed livers.

CONCLUSIONS

Dried distillers' grains with solubles from wheat have feeding and energy values similar to barley in backgrounding diets. In barley-based finishing diets, feeding dried distillers' grains from wheat has minimal effect on performance when included at 20% of diet DM. However, feeding increasing levels increases DMI, but reduces diet energy content and feed conversion as a result of a reduction in the digestibility of the diet.

Table 3. Performance of cattle heifers fed 0, 20, 40, or 60% (DM basis) dried distillers' grains (DDGS) from wheat

	Level of DDGS						P values		
	0%	20%	40%	60%	60% + Ca[z]	SEM	DDGS	Linear	Quadratic
Initial weight (kg)	312.7	312.0	311.1	310.8	312.6	4.2	1.00	0.73	0.95
Final weight (kg)	557.4	562.4	567.7	570.1	558.3	8.7	0.79	0.27	0.88
Day 1 to day 55[x]									
DMI (kg d^{-1})	6.65 ± 0.20	6.72 ± 0.20	6.86 ± 0.11	–	–	–	0.61	0.37	0.88
ADG (kg d^{-1})	0.92 ± 0.06	0.92 ± 0.06	0.95 ± 0.03	–	–	–	0.86	0.65	0.86
Gain:feed	0.134 ± 0.007	0.135 ± 0.007	0.137 ± 0.004	–	–	–	0.94	0.76	0.92
Day 56 to day 188									
DMI (kg d^{-1})	10.50	10.7	11.56	11.72	11.44	0.29	0.01	0.001	0.86
ADG (kg d^{-1})	1.46	1.50	1.57	1.54	1.44	0.04	0.20	0.14	0.43
Gain:feed	0.140	0.140	0.137	0.132	0.127	0.003	0.01	0.04	0.50
DM digestibility (%)	76.4	–	–	68.9	65.8	0.02	0.01		
NEg of diet (MCal kg^{-1})[w]	1.15	1.14	1.09	1.07	1.03	0.02	0.001	0.005	0.65
NEg of DDGS (MCal kg^{-1})	–	1.36	1.27	1.26	1.21	0.06	0.17	0.31	0.59

[z]Extra calcium (as limestone) provided to bring Ca:P ratio to 1.6:1.
[y]Linear and quadratic analyses did not include 60% + Ca treatment.
[x]Cattle fed the 60% or 60% + Ca diets had been fed the 40% DDGS from day 1 to day 55.
[w]Calculated assuming barley NEg content of 1.4 MCal kg^{-1}.

Table 4. Carcass measurements and liver abscesses of cattle fed 0, 20, 40, or 60% (DM basis) dried distillers' grains (DDGS) from wheat

	Level of DDGS						*P* value			
	0%	20%	40%	60%	60% + Ca	SEM	Diet	Linear	Quadratic	Control vs. DDGS
Carcass weight (kg)	334*b*	340*ab*	347*ab*	341*ab*	348*a*	5.10	0.32	0.29	0.27	0.19
Dressing percentage	60.48	60.75	61.35	60.04	62.61	1.28	0.65	0.90	0.55	0.88
Back fat (mm)	9.72*c*	14.06*a*	12.07*ab*	11.67*bc*	11.30*bc*	0.78	0.005	0.28	0.004	0.003
Ribeye area (cm^2)	90.63	89.57	92.79	91.38	95.33	2.45	0.50	0.63	0.95	0.83
Meat yield (%)	60.41*a*	56.98*ab*	58.86*ab*	56.49*b*	59.86*ab*	1.40	0.21	0.16	0.73	0.10
AAA (%)[z]	13.0	43.5	16.7	16.7	25		0.37			
Abscessed livers (%)[z]	4.55	13.04	12.5	13.04	0.0		0.36			
Severely abscessed (%)[z]	4.55	4.35	0.0	8.70	0.0		0.44			

[z]From Chi square analysis.

Energy content (NEg) of dried distillers' grains from wheat declines from 97% of the level in barley, when fed at 20% of diet DM, to 90%, when fed at levels of 40 or 60%. Inclusion of wheat DDGS in the diet had no impact on carcass traits in the present experiment.

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