The Professional Animal Scientist 24 (2008):439–444

Effect of Corn Processing in Finishing Diets Containing Wet Distillers Grains on Feedlot Performance and Carcass Characteristics of Finishing Steers[1]

K. J. Vander Pol,*[2] M. A. Greenquist,* PAS, G. E. Erickson,*[3] PAS, T. J. Klopfenstein,* and T. Robb†

*Department of Animal Science, University of Nebraska, Lincoln, 68583-0908; and †Abengoa Bioenergy, York, NE 68467

ABSTRACT

Three-hundred sixty calf-fed steers (BW = 318 ± 15 kg) were used in a completely randomized design to evaluate corn processing methods in finishing diets containing wet distillers grains plus solubles (WDGS). Whole corn (WC) was compared with corn processed by different methods, consisting of dry-rolled corn (DRC), high-moisture corn (HMC), a 1:1 DRC:HMC combination (DM basis), steam-flaked corn (SFC), and finely-ground corn (FGC). The SFC with a flake density of 0.33 kg/L was obtained from a commercial feedlot. Basal dietary ingredients consisted of ground alfalfa hay (5.6% of DM) and dry supplement (3.0% of DM), with the balance being WDGS (30% of DM) and corn (61.4% of DM). Final BW and ADG were greater ($P < 0.05$) for the cattle fed DRC (1.84 kg/d) compared with cattle fed FGC (1.53 kg/d), SFC (1.63 kg/d), and WC (1.75 kg/d), but was not different ($P = 0.11$) from cattle fed DRC:HMC (1.78 kg/d). Cattle fed HMC (0.185) had greater ($P < 0.05$) G:F compared with cattle fed FGC (0.166), SFC (0.176), and WC (0.166). No differences ($P > 0.30$) were detected between cattle fed HMC and DRC:HMC for ADG and G:F; however, cattle fed DRC tended to have greater ($P = 0.08$) ADG, yet lower ($P = 0.08$) G:F than cattle fed HMC. Carcass characteristics reflected performance. These data indicate that steam flaked and finely ground corn processing methods, or no processing, are not as effective as high-moisture or dry-rolled corn processing methods in finishing diets containing 30% WDGS.

Key words: corn processing, feedlot cattle, wet distillers grains plus solubles

INTRODUCTION

Starch utilization is fundamental to improving feedlot production efficiency (Theurer, 1986). A common method of improving starch utilization is grain processing, which increases starch availability (Owens et al., 1997). Cooper et al. (2002) reported that total tract starch digestion improved from 96.1% for dry-rolled corn to 99.8% for steam-flaked corn when fed at 90% of the diet (DM basis). Owens et al. (1997) reported a 14% increase in ME for steam-flaked corn, and a 5% increase in ME for high-moisture corn based finishing diets relative to dry-rolled corn based finishing diets. However, as starch utilization increases, the risk of ruminal acidosis also increases (Huntington, 1997).

[1] A contribution of the University of Nebraska Agricultural Research Division, supported in part by funds provided through the Hatch Act.
[2] Present address: Koers-Turgeon Consulting; 1373 Golden Hills Ln., Piedmont, OK 73078.
[3] Corresponding author: geericks@unlnotes.unl.edu

Corn milling byproducts (wet corn gluten feed, **WCGF**; or wet distillers grains plus solubles, **WDGS**) are increasing in supply and are excellent energy substitutes for feedlot cattle (Klopfenstein et al., 2008). These byproducts are concentrated in nutrients present in grain (except starch) because the starch, which comprises approximately two-thirds of the grain, is removed (Stock et al., 2000). As a result, feeding WCGF reduces subacute acidosis (Krehbiel et al., 1995); however, feeding WDGS does not appear to reduce acidosis (Vander Pol et al., 2008). Macken et al. (2006b) reported improvements in NE_g of 10.3 and 15.4% for high-moisture and steam-flaked corn, respectively, relative to dry-rolled corn in finishing diets containing 25% WCGF (DM basis). These data suggest that the impact of grain processing and its effect on starch utilization is enhanced when WCGF is included in finishing diets with more intensely processed corn (Scott et al., 2003; Macken et al., 2006b).

However, the difference in energy value between more intensive corn processing methods (high-moisture, steam-flaking) and less intensive corn processing methods (whole, dry-rolling) has not been evaluated in diets containing WDGS. Therefore, the objective of this trial was to determine the effects of 6 different corn processing methods in diets containing 30% WDGS (DM basis) on feedlot performance and carcass characteristics of finishing steers.

MATERIALS AND METHODS

Three-hundred sixty large-framed, crossbred (British × Continental) steer calves (BW = 318 ± 15 kg) were used in a completely randomized design. In October 2004, steers were procured from 3 order buyers with access to ranch direct and sale barn sources of calves. Upon arrival at the University of Nebraska Agricultural Research and Development Center research feedlot near Mead, NE, steers were identified with a panel and electronic identification tag (Allflex USA, Dallas, TX), weighed, vaccinated (*Hemophilus Somnus* Bacterin, Schering Plough Animal Health, Union, NJ; Pyramid-5 and Presponse, Fort Dodge Animal Health, Overland Park, KS; Vision-7 with Spur, Intervet, Millsboro, DE), poured with a parasiticide (moxidectin; Cydectin, Fort Dodge Animal Health), and weaned on smooth bromegrass pastures for approximately 3 wk. Five days before the initiation of this trial, steers were placed in feedlot pens and limit-fed a diet consisting of 50% WCGF and 50% alfalfa hay (DM basis) at 2% of BW. During limit-feeding, steers had ample bunk space (46 cm) to ensure all steers equal access to feed. Steers were weighed individually on d 0 and d 1, and all steers were implanted with Synovex-C (10 mg of estradiol benzoate; Fort Dodge Animal Health). Utilizing BW obtained on d 0, steers were stratified by BW and assigned randomly to pen (10 steers/pen). Pen was assigned randomly to dietary treatment and served as the experimental unit (6 pens/treatment).

The dietary treatments (Table 1) consisted of feeding whole corn (**WC**) or 5 different corn processing method treatments fed at 61.4% of diet DM. Processing methods were steam-flaked corn (**SFC**), high-moisture corn (**HMC**), dry-rolled corn (**DRC**), DRC and HMC fed at a 1:1 ratio (DM basis; **DRC:HMC**), and finely-ground corn (**FGC**). Basal dietary ingredients consisted of 30% WDGS, 5.6% alfalfa hay, and 3% dry meal supplement (DM basis). Dry matter determinations were conducted weekly on all ingredients by drying samples in a 60°C forced air oven for 48 h. Diets were formulated to meet or exceed the NRC (1996) requirements for degradable intake protein, metabolizable protein, Ca, P, K, and trace minerals. Adaptation to final finishing diets consisted of a 21-d period and 4 diets fed for 3, 4, 7, and 7 d, with 45, 35, 25, and 15% alfalfa hay, respectively. Alfalfa hay was replaced by the respective corn in each treatment and WDGS was included at 30% of DM in all diets from d 1. Bunks were visually assessed at 0630 h each morning and DM offered was adjusted according to the amount of feed remaining. Steers were fed once daily at approximately 0830 h with a feed truck equipped with scales and a Roto-Mix (Model 420, Roto-Mix, Dodge City, KS) mixer-delivery box. Feed refusals were taken at the discretion of the unit manager and usually corresponded to periods of inclement weather (snow, rain, etc.) or on the day cattle were weighed (reimplanting). Refusals were analyzed for DM by drying in a 60°C forced air oven for 48 h.

Steers were reimplanted on d 66 with Revalor-S (Intervet, Millsboro, DE) and fed for a total of 168 d. Before shipping, all pens were weighed on a pen scale (Norac, model MASM7-20EA, Norac Systems Int. Inc., Saskatoon, SK, Canada) to determine final live BW and calculation of dressing percentage. All final live BW values were shrunk 4%. Dressing percentage on a pen mean basis was calculated by dividing hot carcass weight (**HCW**) by shrunk final live BW. On day of shipping, steers were fed 50% of the previous day's DM offered and were shipped at 2000 h. Steers were slaughtered at 0630 h on d 169 at a commercial packing plant (Greater Omaha Pack, Omaha, NE) where HCW and liver scores were recorded (Brink et al., 1990). Following a 48-h chill, fat thickness, LM area, KPH, and USDA-called marbling score were recorded. Yield grade was calculated utilizing the equation YG = 2.50 + 6.35× fat thickness (cm) − 2.06 × LM area (cm^2) + 0.2 × KPH (%) + 0.0017 × HCW (kg; Boggs and Merkel, 1993). Carcass adjusted final BW, ADG, and G:F were calculated using HCW divided by dressing percentage, which was done to minimize error associated with gastrointestinal fill and to provide an accurate estimate of individual final BW. Throughout the duration of this trial, 9 steers were removed due to illness or death (3 HMC, 2 DRC, 2 FGC, 2 DRC:HMC), and the data from these steers were not included in the analysis. For calculation of DMI of the pen, these steers were assumed to consume average DMI for that pen up until the day of removal or death.

Fecal grab samples were randomly obtained from 5 steers/pen at the time of reimplanting (d 66). Approximately 10 mL of as-is fecal material from the 5 individual steers were composited by pen (approximately 50 g of feces). Fecal composites were stored frozen, freeze-dried, ground to pass through a 1-mm screen, and analyzed at a commercial laboratory (SDK Labs, Hutchinson, KS) for total starch (Xiong et al., 1990).

With the exception of the SFC, all corn used was produced from the same seed-corn hybrid (Pioneer #33B51, Pioneer Hybrid International, Johnston, IA) and grown in similar fields under irrigation to reduce the effect of corn hybrid on feeding performance. Dry-rolled corn was processed through a single-roll roller mill. Finely-ground corn was processed through a hammermill to pass through a 0.95-cm screen. High-moisture corn was harvested in 1 d at approximately 32% moisture, processed through a single-roll roller mill and ensiled in a plastic silo bag for 55 d before feeding began. Steam-flaked corn was produced at a commercial feedlot (Mead Cattle Company, Mead, NE), targeting a flake density of 0.33 kg/L (26 lb/bushel), and was delivered twice per week. Wet distillers grains plus solubles were procured from a commercial ethanol plant (Abengoa Bioenergy, York, NE) using corn grain and were delivered on an as-needed basis to the research facility (approximately once per week). The WDGS averaged 32.6% DM, 32.2% CP, and 12.1% ether extract during this experiment.

For steer performance, carcass characteristics, and fecal starch, the pen mean served as the experimental unit. Data were analyzed using the mixed procedures of SAS (Version 9.1, SAS Inst. Inc., Cary, NC) as a completely randomized design. Treatment means were compared when the F-test statistic for treatment was significant, with least squares means separated using the least significant difference method, and $P \leq 0.05$ considered significant.

Animal care for this experiment complied with procedures approved by the University of Nebraska Institutional Animal Care and Use Committee.

RESULTS AND DISCUSSION

Degree of processing is based on fecal starch concentrations (Table 2). Degree of processing increased as follows: WC, FGC, DRC, DRC:HMC, HMC, and SFC. With the exception of FGC, DMI decreased as degree of processing increased from WC to SFC. Cattle fed WC diets had the greatest ($P < 0.05$) DMI, and steers fed DRC, HMC, or DRC:HMC had greater DMI ($P < 0.05$) than cattle fed FGC or SFC. Average daily gain (Table 2) was not different for cattle fed HMC compared with DRC:HMC. Likewise, cattle fed DRC had similar ADG as cattle fed DRC:HMC. However, cattle fed DRC tended ($P = 0.08$) to have greater ADG than steers fed HMC. Cattle fed DRC, HMC, or DRC:HMC had greater ($P < 0.05$) ADG than FGC or SFC. Feeding WC was intermediate and not different from ADG of cattle fed HMC or DRC:HMC. Cattle fed HMC had greater ($P < 0.05$) G:F than cattle fed FGC, SFC, and WC diets, with a tendency ($P = 0.08$) for the cattle fed HMC to be more efficient than cattle fed DRC (0.185 vs. 0.179). The cattle fed the HMC diet were more efficient because they had lower DMI and similar ADG as cattle fed the DRC diet. Cattle fed DRC had similar G:F to cattle fed SFC. Interestingly, no marked differences were observed between DRC, HMC, and SFC in terms of G:F in this study with 30% WDGS. However, feeding WC decreased G:F by 7.3% for the whole diet compared with cattle fed DRC, which suggests an 11.8% (7.3%/61.4% inclusion of corn) decrease in G:F due to the corn processing method (the only diet component changed). The same depression in G:F was observed for cattle fed FGC, primarily due to lower ADG. It appears that FGC does not work well in diets containing 30% WDGS, which was surprising as the WDGS should aid in mixing and prevent fines.

Table 1. Composition of dietary treatments and nutrient composition of finishing diets containing corn processed by different methods and 30% WDGS

Ingredient	% of diet DM
Corn[1]	61.4
WDGS[2]	30.0
Alfalfa hay	5.6
Dry supplement	3.0
Limestone	1.42
Finely ground corn	0.64
Potassium chloride	0.47
Salt	0.30
Tallow	0.08
Trace mineral premix[3]	0.05
Rumensin-80 premix[4]	0.02
Vitamin A, D, and E premix[5]	0.01
Tylan-40 premix[6]	0.01
Nutrient composition[7]	
CP, %	16.6 to 16.8
Calcium, %	0.63 to 0.65
Phosphorus, %	0.39 to 0.46
Potassium, %	0.86 to 0.92
Sulfur, %	0.30 to 0.32
Ether extract, %	6.0 to 6.8

[1]Corn fed as whole corn, finely-ground corn, dry-rolled corn, a dry-rolled corn + high-moisture corn combination, high-moisture corn, or steam-flaked corn.

[2]WDGS = wet distillers grains plus solubles.

[3]Premix contained 10% Mg, 6% Zn, 4.5% Fe, 2% Mn, 0.5% Cu, 0.3% I, and 0.05% Co.

[4]Premix contained 176 g/kg monensin.

[5]Premix contained 1,500 IU/g vitamin A, 3,000 IU/g vitamin D, and 3.7 IU/g vitamin E.

[6]Premix contained 88 g/kg tylosin.

[7]Nutrient analysis performed on all ingredients; range represents variation across all 6 diets.

Table 2. Performance[1] of steers fed 30% wet distillers grains plus solubles and corn from 6 different processing methods[2]

Item	WC	FGC	DRC	DRC:HMC	HMC	SFC	SEM	*F*-test
Initial BW, kg	317.9	319.5	318.0	317.9	317.6	317.6	0.5	0.07
Live final BW,[3] kg	611.6[b]	586.6[c]	625.3[a]	613.4[ab]	614.3[ab]	597.0[b]	4.3	<0.01
Adjusted final BW,[4] kg	611.5[b]	577.2[d]	626.9[a]	615.6[ab]	614.0[ab]	591.6[c]	4.9	<0.01
DMI, kg/d	10.50[a]	9.26[c]	10.28[b]	9.75[b]	9.53[bc]	9.28[c]	0.10	<0.01
ADG, kg[4]	1.75[b]	1.53[d]	1.84[a]	1.78[ab]	1.77[ab]	1.63[c]	0.03	<0.01
G:F[4,5]	0.166[c]	0.166[c]	0.179[ab]	0.182[ab]	0.185[a]	0.176[b]	0.002	<0.01
Fecal starch, %	15.9[a]	13.4[a]	12.0[ab]	12.0[ab]	8.7[b]	4.2[c]	1.3	<0.01

[a–d]Means within a row with unlike superscripts differ (*P* < 0.05).

[1]Each treatment contained 6 pens, with 10 steers/pen fed 168 d.

[2]WC = whole corn, FGC = fine ground corn, DRC = dry-rolled corn, HMC = high-moisture corn, DRC:HMC = 1:1 DRC + HMC blend (DM basis), and SFC = steam-flaked corn.

[3]Final live BW shrunk 4%.

[4]Calculated from hot carcass weight divided by the average dressing percentage of 63.

[5]Calculated as total feed intake (DM basis) divided by total gain.

Carcass characteristics are presented in Table 3. Performance was based on HCW; therefore, similar responses were observed in final BW, HCW, and ADG across corn processing treatments. Marbling score was similar for steers fed WC, DRC, HMC, and DRC:HMC, but were greater ($P < 0.05$) for steers fed FGC and SFC. Fat depth was similar between cattle fed WC, DRC, and HMC, but was less ($P < 0.05$) for cattle fed SFC and FGC. Longissimus muscle area was not different among treatments ($P = 0.16$). Cattle fed DRC had a significantly greater ($P < 0.05$) calculated USDA YG than cattle fed the FGC, SFC, HMC, and DRC:HMC diets. Cattle fed FGC and SFC had lower ($P < 0.05$) USDA YG than all other treatments. Evaluating the USDA marbling score, USDA YG, and fat depth data suggests that cattle performance was the primary factor explaining differences in carcass characteristics, because all steers were fed the same number of days. Particularly, ADG appears to match carcass fatness based on fat depth and marbling score.

According to Zinn et al. (2002), fecal starch content may indicate the degree to which starch is utilized. In a more recent article, Zinn et al. (2007) observed a significant quadratic relationship between fecal starch percent and starch digestibility with a good fit ($R^2 = 0.96$). Although measuring total tract starch

Table 3. Carcass characteristics of steers fed 30% wet distillers grains plus solubles and corn from 6 different processing methods[1]

Item	WC	FGC	DRC	DRC:HMC	HMC	SFC	SEM	*F*-test
Hot carcass weight, kg	385.2[b]	363.7[d]	394.9[a]	387.8[ab]	386.9[ab]	372.7[c]	3.1	<0.01
Dressing %	62.9	62.0	63.2	63.3	63.0	62.5	0.3	0.06
Marbling score[2]	533.8[a]	486.8[b]	540.2[a]	527.7[a]	544.2[a]	495.8[b]	10.3	<0.01
% Choice	60.0	46.1	63.5	62.4	65.0	48.3	5.3	0.06
% Upper 2/3 Choice	23.3[ab]	10.4[bc]	29.4[a]	19.6[ac]	28.0[ab]	6.7[c]	5.1	0.01
LM area, cm^2	82.6	80.6	83.9	84.5	85.1	81.3	1.3	0.16
12th rib fat, cm	1.50[ab]	1.14[c]	1.57[a]	1.40[b]	1.47[ab]	1.30[c]	0.05	<0.01
KPH fat, %	2.08[a]	1.87[c]	2.08[a]	1.98[a]	1.98[ab]	1.92[bc]	0.04	<0.01
YG[3]	3.49[ab]	3.06[c]	3.62[a]	3.30[b]	3.37[b]	3.22[c]	0.08	<0.01

[a–d]Means within a row with unlike superscripts differ (*P* < 0.05).

[1]WC = whole corn, FGC = fine ground corn, DRC = dry-rolled corn, HMC = high-moisture corn, DRC:HMC = 1:1 DRC + HMC blend (DM basis), and SFC = steam-flaked corn.

[2]Where 400 = Slight 0, 500 = Small 0.

[3]YG = 2.50 + 6.35 × fat thickness (cm) – 2.06 × LM area (cm^2) + 0.2 × KPH (%) + 0.0017 × HCW (kg).

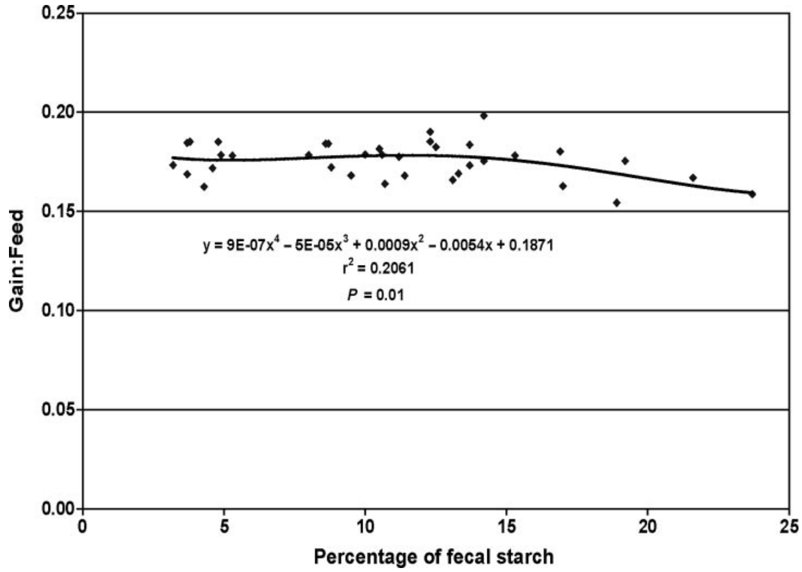

Figure 1. Relationship between fecal starch (%) and observed G:F for cattle fed corn from 1 of 6 corn processing methods in diets containing 30% wet distillers grains plus solubles.

digestion is useful, percentage starch in the fecal DM may be sufficient for comparisons between corn processing methods in diets comprised of similar ingredients. In the present study, fecal starch was greatest for WC and least ($P < 0.05$) for SFC. With the exception of DRC, the absolute values for fecal starch observed in the present study are in close agreement with those published by Macken et al. (2006b). These authors further observed a significant linear decrease in G:F as the amount of fecal starch increased. The relationship between G:F and fecal starch for the present study is presented in Figure 1. The highest order polynomial that was significant ($P < 0.05$) and had the best fit ($r^2 = 0.2061$) was a quartic response. The lack of a linear response in the present study may be explained by the greater G:F for cattle fed diets with a lesser degree of processing (HMC and DRC) compared with cattle fed grains having a higher degree of processing (SFC).

The hypothesis was that cattle fed more intensely processed corn would have increased ADG, G:F, or both, in diets with WDGS. This was not the case. In general, ADG was decreased and G:F was unaffected when SFC was compared with DRC. It appears that HMC was not different than feeding DRC, and WC was not as efficient as DRC.

Based on previous research (Vander Pol et al., 2006) in which the optimum inclusion of WDGS was 30 to 40% when fed with a DRC:HMC blend, 30% WDGS was fed on a DM basis in the present study. However, the optimum inclusion may vary depending on corn processing method (Klopfenstein et al., 2008). Daubert et al. (2005) fed WDGS from sorghum and concluded that the optimum level of WDGS in steam-flaked corn diets was 16%. However, because their experiment was evaluating sorghum wet distillers, it is not clear what influence that may have on optimum inclusion. Caution is required when comparing results from feeding WDGS derived from sorghum with WDGS derived from corn, as numerical differences have consistently suggested that WDGS from corn is likely somewhat higher in energy than WDGS from sorghum (Al-Suwaiegh et al., 2002); yet differences between WDGS from corn and WDGS from sorghum were not significant within multiple experiments where the 2 types of WDGS have been compared (Klopfenstein et al., 2008).

Comparisons can be made between this study where WDGS were fed and other research where corn processing was evaluated in diets with no byproducts or in diets with WCGF, which is also derived from corn with the starch removed. In diets containing WCGF where corn processing method was evaluated, Macken et al. (2006b) observed greater DMI for steers fed DRC compared with HMC and SFC when WCGF was included in diets at 25% of diet DM. However, in their study, G:F was increased when steers were fed SFC, which was greater than for cattle fed either HMC or DRC. Feeding HMC also increased G:F compared with DRC. Macken et al. (2006b) fed 60% corn with 25% WCGF, so the relative change in G:F was 20.1% greater for cattle fed SFC and 13.3% greater for cattle fed HMC compared with their DRC treatment. In 2 separate experiments by Scott et al. (2003), the authors observed that SFC fed cattle had 12.7 and 16.6% greater G:F compared with cattle fed DRC in diets containing 32 and 22% WCGF, respectively. Scott et al. (2003) did observe variable responses to HMC compared with DRC with a 9.5% improvement for HMC compared with DRC when 32% WCGF was fed, and no difference between HMC and DRC when 22% WCGF was fed. Only one experiment has compared WC to DRC in diets containing WCGF, which resulted in a 12.7% reduction in G:F due to the corn fraction with 32% WCGF (Scott et al., 2003). An 11.8% reduction in G:F was observed in the current study when WC was fed compared with DRC, which is numerically similar to Scott et al. (2003).

Interestingly, that the cattle fed DRC and HMC had greater ADG compared with SFC is a bit surprising in this study. Corona et al. (2005) observed that cattle fed SFC had greater ADG than cattle fed DRC, ground corn, or WC in diets with no byproducts. Cattle fed DRC or ground corn had greater ADG compared with cattle fed WC (Corona et al., 2005). In a review by

Owens et al. (1997), in diets containing no byproduct, cattle receiving HMC had lower ADG than cattle receiving DRC. However, calculated energy values for SFC have consistently been 12 to 18% greater than DRC (Owens et al., 1997; Zinn et al., 2002). In a review by Zinn et al. (2002), ADG was increased by 6.6% and G:F was increased by 15.0% for cattle fed SFC compared with DRC; however, these improvements are for the entire diet. Combining 3 experiments that compared SFC to DRC in diets with WCGF (Scott et al., 2003; Macken et al., 2006b), SFC resulted in a 16.5% improvement in G:F due to the corn fraction (average inclusion of 58.3% of diet DM). However, an increase in ADG from feeding SFC compared with DRC was observed in only 1 of the 3 experiments and was relatively small (1.92 kg/d for SFC fed cattle and 1.83 kg/d for DRC fed cattle). In this study, the surprising results are that cattle fed SFC gained less than cattle fed DRC and HMC. Likewise, G:F were not markedly different between DRC, HMC, and SFC.

Macken et al. (2006a), evaluating the cost of corn processing, showed that the costs of steam-flaking or ensiling HMC were greater than the costs associated with dry-rolling corn. However, these authors further suggested that the improvement in G:F typically observed with SFC and HMC compared with DRC tends to offset the greater costs associated with processing. Those authors calculated that an improvement of 1.7 and 4.2% would be necessary to break even on replacing DRC with HMC and SFC, respectively, for a 20,000-head feedlot. Results from the present study suggest that steam-flaking was not as effective as ensiling high-moisture or dry-rolled corn in diets containing 30% WDGS (DM basis). Therefore, the costs associated with steam-flaking may not be offset in diets containing 30% WDGS (DM basis).

IMPLICATIONS

The results of this experiment suggest that more intensive corn processing methods such as steam flaking, as well as feeding whole corn or FGC, are not as beneficial on performance in finishing diets containing 30% WDGS as high-moisture or dry-rolled corn. If WDGS are used in finishing diets, then dry-rolling or high-moisture corn would be optimum in terms of performance and costs. Optimum inclusion of WDGS in finishing diets may depend on corn processing method.

LITERATURE CITED

Al-Suwaiegh, S., K. C. Fanning, R. J. Grant, C. T. Milton, and T. J. Klopfenstein. 2002. Utilization of distillers grains from the fermentation of sorghum or corn in diets for finishing beef and lactating dairy cattle. J. Anim. Sci. 80:1105.

Boggs, D. L., and R. A. Merkel. 1993. Beef carcass evaluation, grading, and pricing. p. 105 in Live Animal Carcass Evaluation and Selection Manual. Kendall/Hunt Publ. Co., Dubuque, IA.

Brink, D. R., S. R. Lowry, R. A. Stock, and J. C. Parrott. 1990. Severity of liver abscesses and efficiency of feed utilization of feedlot cattle. J. Anim. Sci. 68:1201.

Cooper, R. J., C. T. Milton, T. J. Klopfenstein, T. L. Scott, C. B. Wilson, and R. A. Mass. 2002. Effect of corn processing on starch digestion and bacterial crude protein flow in finishing cattle. J. Anim. Sci. 80:797.

Corona, L., S. Rodriguez, R. A. Ware, and R. A. Zinn. 2005. Comparative effects of whole, ground, dry-rolled, and steam-flaked corn on digestion and growth performance in feedlot cattle. Prof. Anim. Sci. 21:200.

Daubert, R. W., J. S. Droulliard, E. R. Loe, J. J. Sindt, B. E. Depenbusch, J. T. Fox, M. A. Greenquist, and M. E. Corrigan. 2005. Optimizing use of wet sorghum distillers grains with solubles in flaked-corn finishing diets. p 15 in Kansas State Beef Cattle Res. Rep. Kansas State Univ. Agric. Exp. Stn. and Coop. Ext. Serv., Manhattan.

Huntington, G. B. 1997. Starch utilization by ruminants: From basics to the bunk. J. Anim. Sci. 75:852.

Klopfenstein, T. J., G. E. Erickson, and V. R. Bremer. 2008. Board-Invited Review: Use of distillers by-products in the beef cattle feeding industry. J. Anim. Sci. 86:1223.

Krehbiel, C. R., R. A. Stock, D. W. Herold, D. H. Shain, G. A. Ham, and J. E. Carulla. 1995. Feeding wet corn gluten feed to reduce subacute acidosis in cattle. J. Anim. Sci. 73:2931.

Macken, C. N., G. E. Erickson, and T. J. Klopfenstein. 2006a. The cost of corn processing for finishing cattle. Prof. Anim. Sci. 22:23.

Macken, C. N., G. E. Erickson, T. J. Klopfenstein, and R. A. Stock. 2006b. Effects of corn processing method and protein concentration in finishing diets containing wet corn gluten feed on cattle performance. Prof. Anim. Sci. 22:14.

NRC. 1996. Nutrient Requirements of Beef Cattle. Update 2000. Natl. Acad. Press, Washington, D.C.

Owens, F. N., D. S. Secrist, W. J. Hill, and D. R. Gill. 1997. The effect of grain source and grain processing on performance of feedlot cattle: A review. J. Anim. Sci. 75:868.

Scott, T. L., C. T. Milton, G. E. Erickson, T. J. Klopfenstein, and R. A. Stock. 2003. Corn processing method in finishing diets containing wet corn gluten feed. J. Anim. Sci. 81:3182.

Stock, R. A., J. M. Lewis, T. J. Klopfenstein, and C. T. Milton. 2000. Review of new information on the use of wet and dry milling feed by-products in feedlot diets. Proc. Am. Soc. Anim. Sci. http://www.asas.org/jas/symposia/proceedings/0924.pdf Accessed May 29, 2003.

Theurer, C. B. 1986. Grain processing effects on starch utilization by ruminants. J. Anim. Sci. 63:1649.

Vander Pol, K. J., G. E. Erickson, T. J. Klopfenstein, M. A. Greenquist, and T. Robb. 2006. Effect of dietary inclusion of wet distillers grains on feedlot performance of finishing cattle and energy value relative to corn. Nebraska Beef Rep. MP 88-A:51.

Vander Pol, K. J., M. K. Luebbe, G. I. Crawford, G. E. Erickson, and T. J. Klopfenstein. 2008. Performance and digestibility characteristics of finishing diets containing distillers grains, composites of rcorn processing coproducts, or supplemental corn oil. J. Anim. Sci. (accepted)

Xiong, Y., S. J. Bartle, and R. L. Preston. 1990. Improved enzymatic method to measure processing effects and starch availability in sorghum grain. J. Anim. Sci. 68:3861.

Zinn, R. A., A. Barreras, L. Corona, F. N. Owens, and R. A. Ware. 2007. Starch digestion by feedlot cattle: Predictions from analysis of feed and fecal starch and nitrogen. J. Anim. Sci. 85:1727.

Zinn, R. A., F. N. Owens, and R. A. Ware. 2002. Flaking corn: Processing mechanics, quality standards, and impact on energy availability and performance of feedlot cattle. J. Anim. Sci. 80:1145.