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Evaluation of Condensed Distillers Solubles and Field Peas for Feedlot Cattle

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EVALUATION OF CONDENSED DISTILLERS SOLUBLES AND FIELD PEAS FOR FEEDLOT CATTLE

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Limited previous research has investigated feeding high levels of condensed distillers solubles (CDS) as an energy source for feedlot cattle. As an energy dense and relatively inexpensive by-product feed from ethanol production, CDS may provide another opportunity to replace high priced corn in finishing diets. Two feedlot studies and one metabolism study were conducted to evaluate the effects of feeding CDS in both corn-based diets, and in combination with other by-product feeds on cattle performance and carcass characteristics. Inclusion of up to 36% CDS, providing 9.4% dietary fat improved performance relative to a corn-based control, with the optimum level of CDS being approximately 27% of diet DM. Optimum inclusion of CDS in diets containing modified distillers grains plus solubles appears to be lower than in diets containing Synergy (a blend of wet corn gluten feed and modified distillers grains) and depends on the nutrient content of the basal diet. Feeding CDS in either a corn-based diet or in combination with wet distillers grains plus solubles (WDGS) had no effect on nutrient digestibility, but slightly decreased acetate to propionate ratio. Dietary fat and sulfur content must be monitored in these diets to avoid potential negative effects on animal performance. In an effort to further evaluate how alternative feeds interact with diets containing ethanol by-product feeds, a finishing trial was conducted to evaluate the addition of 20% field peas to diets with or without 30% WDGS. Both peas and WDGS improved feed efficiency relative to the corn-based control, however the combination of the two feeds interacted, with performance of those cattle being intermediate to those fed either peas or WDGS only. Condensed distillers solubles and field peas can replace a portion of the corn in finishing diets while maintaining or improving cattle performance.

Key words: beef cattle, by-products, distillers solubles, field peas

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REVIEW OF LITERATURE

Characterizing Condensed Distillers Solubles

The Process. Increased grain-based fuel ethanol production in recent years has led to rapid growth in the availability and use of ethanol by-products as livestock feed ingredients. Ethanol is produced through dry and wet corn milling processes, both of which have been described in detail by Stock et al. (2000), and each produce a unique set of by-product feeds. The most commonly used process for ethanol production is dry-milling, which can utilize a variety of grain qualities and types. Distillers grains are composed of the solid feed particles that are left after fermentation of grain, distillation of the ethanol portion, and liquid separation through either the screening or centrifugation of whole stillage. These grains can be dried to varying degrees, resulting in wet (no drying), modified (partially dried), or dry (dried to 10% moisture) distillers grains. The liquid portion of whole stillage is known as thin stillage, which is further evaporated to produce condensed distillers solubles (CDS), sometimes referred to as syrup. The CDS can then either be blended with distillers grains, creating distillers grains plus solubles (DGS), or can be marketed as a separate liquid feed ingredient. The fate of CDS is largely dependent on individual ethanol plants' liquid storage capacity. Often, supply of CDS exceeds storage availability, allowing CDS to be purchased by livestock producers at a competitive price relative to other by-product feeds and energy sources.

The Product. As with most by-products, the composition of CDS is variable, both across and within ethanol plants. According to Lardy (2007), CDS can range from 23-45% DM, and contains 20-30% CP, 80% of which is ruminally degradable; 9-15%

ether extract; and 0.37-0.95% sulfur. However, others (Rust et al., 1990; Gilbery et al., 2006; Cao et al., 2009) have reported much higher ether extract values for CDS, up to 34.4%. Because the fat content of CDS is generally higher than that of distillers grains, the composition of distillers grains plus solubles products are very much dependent upon how much CDS is added to the grains by the ethanol plant. This is especially important to consider in diets with high inclusions (30-40%) of DGS, or in forage-based diets (Corrigan et al, 2009), as total dietary fat can get quite high. However, as will be discussed later, there is strong evidence to suggest that the fat provided by DGS and CDS is partially protected from hydrogenation in the rumen and is more digestible than traditional fat sources such as corn oil or tallow.

Much like the increased fat, CDS also contains higher concentrations of sulfur, phosphorus, and other minerals than corn grain or distillers grains. Corn contains about 0.15% sulfur, but instead of the expected 0.45% (a three-fold concentration of nutrients after starch removal), CDS can contain more than 1.0% sulfur. This extra sulfur was added during ethanol production and plant sanitation and remains in the by-product feeds. Total dietary sulfur levels should be managed to reduce the risk of polioencephalomalacia. Excess phosphorus and nitrogen in by-product diets results in more nutrient-rich feedlot manure, which was shown by Luebbe et al. (2011) to release more nitrogen to into the air. These nutrients must be managed to reduce environmental impact.

Fats and Lipids

Basics of fats. Dietary fat for feedlot cattle is most often supplied in the form of triglycerides from plant seeds (corn, soybeans) or animal sources. A triglyceride is made of a glycerol (3-carbon alcohol) backbone with 3 fatty acids attached. In the rumen, microbial enzymes (lipase) cleave off the glycerol from the fatty acids. Glycerol is then broken down into volatile fatty acids, which pass through the rumen wall and are used as energy elsewhere in the body. The fatty acids that were part of the triglyceride are then acted on by rumen microbes. The microbes manipulate fatty acids to produce fatty acids that are branched, have odd-numbered chain lengths, and are more saturated after the addition of hydrogen to reduce the number of double bonds.

Fat that is stored in adipose tissues as triglycerides can be broken down through lipolysis. Lipolysis is a hormonally-controlled process that yields glycerol and fatty acids, which can then be transported throughout the body to be used as an energy source. Once in the mitochondria of the target tissue, fatty acids are oxidized, or broken down 2 carbons at a time to produce acetyl-CoA. This acetyl-CoA is the fuel that enters the tricarboxylic acid cycle to yield energy that can be used for tissue function (Church and Pond, 1988).

Fat in finishing diets. Conventional wisdom says that total dietary fat should be limited to 5% or less to minimize the deleterious effects that excess fat can have on rumen function, namely fiber digestion (Church and Pond, 1988). However, likely realizing that energy density, rather than fiber digestion, is of greater importance in finishing diets; most consulting nutritionists now recommend a maximum dietary fat level of 8% (Vasconcelos and Galyean, 2007). These nutritionists also report that fat is most often supplied by tallow, yellow grease, a combination of sources, and choice white grease. These traditional fat sources may differ from CDS in how they are manipulated by microbes in the rumen.

Fat source and biohydrogenation. The composition of dietary fat versus fat deposited by the animal is very different, indicating that the rumen microbes alter fatty acids. Biohydrogenation in the rumen is the process by which hydrogen ions are added to fatty acids to reduce the number of double bonds; making the fatty acid more saturated and less inhibitory to rumen microbes (Jenkins, 1993). However, the form of fat that is more advantageous to rumen microbes may be exactly opposite that which is of more value for animal performance. Zinn et al. (2000) showed that a decrease in biohydrogenation (more unsaturated fat) results in increased postruminal digestibility and NE value of dietary fat. Findings by Vander Pol et al. (2009) suggest fatty acids from WDGS are not hydrogenated to the same extent as fatty acids from corn oil. Duodenal fatty acid profile was analyzed from steers fed either 40% WDGS, a composite diet composed of corn bran and corn gluten meal, the composite plus corn oil, a corn-based control diet, or the control plus corn oil. Steers fed WDGS had the greatest proportions of unsaturated fatty acids (18:1 *trans*, 18:1, and 18:2) reaching the duodenum, and those fed diets containing corn oil had the least unsaturated fatty acids. The authors proposed that this difference in fatty acids reaching the duodenum to be absorbed may partially explain the greater energy value of WDGS relative to corn. Bremer (2010) saw similar results as steers fed WDGS had a greater proportion of unsaturated fatty acids reaching the omasum than those fed diets containing corn oil, tallow, or CDS as a fat source. This indicates that there is also a difference between WDGS and CDS in terms of extent of biohydrogenation, even though they both originate from corn. However, Bremer (2010) observed similar total tract lipid and fatty acid digestibilities across all diets, rather than more efficient absorption of unsaturated than saturated fatty acids, as was found by Plascencia et al. (2003) and discussed by Vander Pol et al. (2009).

Effects of CDS on performance

Feeding CDS as the sole by-product. Limited research has been conducted to determine the feeding value of CDS in finishing diets. In fact, CDS is often viewed as a liquid to be used to condition dry rations, or as a protein supplement to be included at no more than 10% of the diet (Lardy, 2007). However, with its high fat content, CDS has also been used successfully as an energy source for finishing cattle, replacing a portion of corn. In a metabolism trial, Rust et al. (1990) fed CDS that was 7.56% DM and 22.8% ether extract to steers, both soaked onto the feed and free choice, with and without access to water. When steers were offered CDS as the only liquid, intakes of 20% CDS of diet DM were observed. Feed efficiency was improved, due mostly to a 13.3% decrease in DMI. Metabolizable energy values of 5.05 and 4.68 Mcal/kg calculated for CDS fed soaked onto feed and free choice were both greater than the NRC (1984) value, 3.18 Mcal/kg. In 2 experiments, Gilbery et al. (2006) supplemented 0, 5, 10, or 15% CDS to steers consuming low quality hay. When CDS containing 4.2% fat was fed, total intake increased and digestibility was unchanged. Addition of CDS containing 17.4% fat resulted in increased DMI and ruminal OM and NDF digestibility. Those researchers concluded that CDS is an acceptable rumen degradable protein source for forage-fed cattle.

Trenkle et al. (1997, 2002, and 2004) conducted a series of studies replacing a portion of dry-rolled corn with CDS. Feeding 6.5% CDS with 10% soybean meal resulted in a 5 and 4% improvement in ADG and G:F, respectively, compared to the soybean meal supplemented control. In another study, 0, 4, or 8% CDS were added to a finishing diet. Though not significant, 4% CDS improved ADG 3.2% and G:F 5% compared to the control, while 8% CDS inclusion decreased ADG 6.4% and increased G:F only 1.5% relative to the corn control. This decrease in performance at 8% inclusion suggests there may be a maximum amount of CDS that can be fed. Finally, 0, 4, 8, or 12% CDS were fed to replace corn and urea in finishing diets. No effects on performance were observed with inclusions up to 12% CDS. No differences in carcass characteristics were observed in any of these 3 experiments. Nutrient characteristics of neither the diets nor the CDS fed were reported, so it is unclear whether inclusion of CDS was being limited by dietary fat or sulfur, or by some other mechanism.

Grains to Solubles ratio. Composition of distillers grains, and possibly their effects on cattle performance, is influenced by the ratio of grains to CDS that are blended at the ethanol plant. As mentioned above, CDS has higher fat content than the solid grains fraction. Corrigan et al. (2009) conducted a study to determine the effects that higher proportions of CDS in dried distillers grains plus solubles (DDGS) may have on forage-fed growing steers. Steers were supplemented at 0.25, 0.50, 0.75, and 1.0% of BW with distillers grains that contained 0.0, 5.4, 14.5, 19.1, and 22.1% CDS (as a % of DDGS). Ether extract content of DDGS increased from 6.9% to 12.3% and NDF content for DDGS decreased from 41.1% to 34.1% as proportion of CDS increased. Proportion of CDS in DDGS had no effect on intake or final BW. As CDS level increased, ADG was optimized at lower DDGS supplementation rates, indicating that high ether extract intake with greater proportions of CDS in DDGS may have had negative effects on NDF digestibility of forage (Pavan et al., 2007).

Godsey et al. (2008) took a similar approach to increasing grains-to-CDS ratio in a finishing trial feeding 0, 20, or 40% WDGS. Wet distillers grains without solubles and CDS were blended in three ratios (100:0, 85:15, and 70:30) at feeding. Dietary fat increased from 5.4 to 6.6%, sulfur increased from 0.27 to 0.36%, and NDF decreased from 33.0 to 26.2% with increasing proportions of CDS in WDGS fed at 40% of diet DM. Linear improvements in ADG and G:F were observed as inclusion of by-product increased from 0 to 40%. Increasing proportion of CDS in WDGS had no impact on performance or carcass characteristics within the 20 and 40% of diet DM inclusions. Together, these 2 studies suggest that finishing cattle may tolerate greater proportions of CDS in distillers grains than forage-fed cattle.

Effect of increasing ratio of CDS in distillers grains on DM degradability was evaluated in situ by Cao et al. (2009). Four ratios of wet distillers grains:CDS were mixed: 100:0, 86.7:13.3, 73.3:26.7, and 60:40; a portion of each mix was dried to 92 to 95% DM and a portion was left wet at 32 to 37% DM. Dacron bags were incubated for 0, 3, 6, 12, 18, 24, and 48 h. Ruminally degradable DM was greater for wet DG than for dry, and increased linearly as proportion of CDS increased in both wet and dry DG. However, Wilken (2009) observed artificially high in situ DM and NDF digestibilities when CDS was freeze-dried and placed as the sole ingredient in the Dacron bag. The author attributed this to the small particle size of dried CDS. Though, considering the results seen in the study by Cao et al. (2009), there may not exist the same challenges in getting accurate values for CDS and distillers grains when mixed together.

CDS in Combinations of By-products. Multiple studies have shown that WDGS and wet corn gluten feed (WCGF) are complementary feedstuffs, and that feeding combinations of by-products provides a way to replace more of the expensive grain in finishing diets (Loza et al., 2010). However, little of this research was conducted using CDS as one of the by-products. It is logical that CDS, which is high in fat and low in NDF, would be equally compatible with WCGF.

Lodge et al. (1997) conducted two trials that compared the performance of animals fed diets containing a composite by-product feed formulated to be similar to WDGS. In the first study, lambs fed a diet containing a composite of WCGF, CDS, corn gluten meal, and tallow (dietary lipid, 6.2%) were 27% more efficient than lambs fed WCGF (dietary lipid, 3.1%). In the second study, steers fed a composite of WCGF, corn gluten meal, and tallow (dietary lipid, 8.4%) were 10% more efficient than those fed WCGF (dietary lipid, 6.2%). Though not significant, steers fed the composite with either the tallow or the corn gluten meal removed, were also more efficient than those fed WCGF alone. These differences in performance were at least partially due to the lipid portion of the diets, which is in agreement with Stock et al. (2000), who noted that the response to added fat in WCGF diets has been positive. This improvement in gain and efficiency when fat is added to WCGF was also observed by Herold et al. (1998) and Richards et al. (1998) when 3% tallow was included in the diet.

Bremer (2010) investigated the effects of increasing inclusions of either WDGS or CDS in finishing diets containing 35% WCGF. Increasing WDGS up to 40% of diet

DM resulted in a linear decrease in ADG, with no effect on G:F. No effects on performance were observed when CDS was increased up to 20% of the diet. In fact, performance of steers fed 20% CDS were similar to those fed 26.7% WDGS in combination with 35% WCGF. These two diets had similar fat (6.2 and 5.9%) and sulfur (0.45 and 0.44%) content, respectively. However, the diet containing 40% WDGS was 6.9% fat and 0.52% sulfur. Previous research suggests that while this fat level is not high enough to negatively impact performance (Vander Pol et al., 2006), the excess sulfur may have depressed ADG (Sarturi et al., 2010). These data suggest that addition of CDS to finishing diets already containing other by-products may provide another way to replace even more corn while maintaining energy density and decreasing ration cost. At minimum, adding CDS will interact with other by-products that also provide fat, sulfur, or both.

CDS and Rumen Metabolism

Digestibility. While typically considered to be negative, the effect of fat supplementation on digestibility, especially of fiber, has been variable. Zinn et al. (1989) observed a linear decrease in OM and NDF digestibility when either yellow grease or blended animal vegetable fat inclusion was increased from 0 to 8% in finishing diets. Proposed mechanisms were the physical coating of feed particles by fat, preventing enzymatic attack, and the negative effects that increased fat levels have on protozoa and cellulolytic bacteria. In another study by Zinn (1994), when tallow soap stock was supplemented at 0, 4, 8, and 12% in finishing diets, ruminal and total tract OM digestibility decreased linearly, which the author attributed to the ruminal indigestibility of the supplemental fat. These data indicated that the upper limit for supplemental fat tolerance should be set at 4%. Interestingly, several studies have observed no negative effects on diet digestibility when fat is supplied in the diet by ethanol by-product feed sources. Ham et al. (1994) found that concentrate-fed steers ruminally infused with 20% thin stillage had greater OM digestibility than steers fed wet distillers grain, hominy feed, or wet or dry corn gluten feed. In a study comparing different sources of fat, Bremer (2010) included CDS, tallow, WDGS, or corn oil in finishing diets to provide 8.2-8.6% dietary fat. Total tract DM and NDF digestibility was greatest for CDS. These data support the hypothesis that CDS is digested differently than other fat sources, which seems to hold true in forage diets as well. Gilbery et al. (2006) supplemented up to 15% CDS to steers consuming low-quality forage and observed either no change or an increase in ruminal and total tract OM digestibility. This is in agreement with Corrigan et al. (2009), who supplemented forage-fed steers at 1% of BW with DDG containing either 0 or 22.1% CDS. This level of CDS had depressed ADG in a separate experiment, but no differences in DM, OM, or NDF digestibility were observed. Only a slight tendency (P = 0.14) existed for NDF digestibility to be greater for steers fed DDG containing no CDS than for those fed DDG with 22.1% CDS.

Effects on VFA profile and Ruminal pH. The effects of fat and CDS inclusion on ruminal pH and VFA profile have been relatively consistent in the literature, as generally, pH decreases or is unaffected and acetate to propionate ratio (A:P) decreases. As supplemental fat from yellow grease or blended animal-vegetable fat increased, Zinn (1989) saw no change in pH while acetate decreased and propionate increased. In studies that included CDS in finishing diets (Ham et al., 1994; Bremer, 2010), ruminal pH decreased and propionate increased or tended to increase, except in the case of Rust et al. (1990), who saw no effect of CDS on pH or VFA profile. When Gilbery et al. (2006) added up to 15% CDS to low-quality hay, a linear decrease in acetate and increase in propionate were observed, resulting in a decreased A:P ratio. This shift in A:P ratio is due to the inhibitory effect that fat supplementation has on gram positive bacteria, much like an ionophore. Added fat causes the rumen environment to favor gram negative bacteria, which produce more propionate, thus decreasing A:P ratio (Nagaraja, T. G. Kansas State Univ., Manhattan, KS. Personal communication).

Characterizing Field Peas

Field pea production. With almost every farm input increasing in cost, livestock producers are looking for alternative feed sources. These alternative feeds are most effective when they are plentiful, locally sourced, and most importantly, competitively priced. Field peas have gained popularity in recent years among farmers and cattle feeders in the Northern Plains. Seven-hundred fifty-six thousand acres of field peas were planted in 2010 (NASS, 2011). Many of these peas entered the relatively high value human food market, while the portion of the crop that does not meet quality standards for human consumption may be available to livestock producers as an alternative feed grain. However, in some areas, such as western Nebraska, where there is no established food market, the entire crop goes to animal feed. The fact that field peas are a legume, thus fixing nitrogen in the soil, provides an incentive for farmers to plant them for agronomic benefits to the fields. Field peas are also convenient to incorporate into a farming operation, as they utilize common grain planting and harvesting equipment.

Nutrient Composition. In general, field peas are a medium-protein, energy-dense grain with an energy content (NE_g) that has been calculated as both similar to corn (Loe et al., 2004), and lower than that of corn (Fendrick et al., 2005a). Depending on variety, crude protein of field peas can range from 17 to 26.7%, but is typically 23-25% (Anderson et al., 2007). Protein in field pea grain is higher in ruminally degradable protein than corn, with estimates of RDP varying from 78 to 94% (Anderson et al., 2007). However, corn is higher in starch and lower in NDF content (Gilbery, et al., 2007). Rate of starch fermentation in field pea grain is slower than barley or wheat, and about the same as corn (Anderson et al., 2007). Finally, field pea grain has been shown to be palatable when included in rations for various classes of cattle. Therefore, field peas appear to be a viable candidate for inclusion in diets for nursing calves, growing and finishing cattle, and cows as a protein or energy source or both.

Field Pea use in diets for various classes of beef cattle

Creep Diets. Field peas can be especially useful in creep feeding diets for nursing calves because of their palatability and nutrient density. Two studies fed increasing levels of field peas replacing wheat middlings in creep diets. Anderson (1999) found that DMI and ADG increased while G:F decreased as field peas increased from 0 to 100% of the diet, and determined that the optimum level of peas was 33 to 67% of the diet. However, Landblom et al. (2000) found no differences in calf performance as field peas replaced up to 100% wheat middlings. In a study that evaluated the effect of processing field pea grain for creep diets, Anderson et al. (2006) found that at 40% inclusion, calves fed dry-rolled peas tended to have greater daily gains than those fed ground or whole field peas. Dry-rolling may be the optimal amount of processing as the starch is more readily available than in the whole pea, but still provides better ration acceptability and lower risk of acidosis than ground peas. This is similar to results seen by Turgeon et al. (1983), due to varying degrees of corn processing.

Receiving Diets. Multiple studies have evaluated the use of field peas as replacement for other cereal grains in receiving diets for newly-weaned calves, finding fairly consistent results. Anderson and Stoltenow (2002) received calves on a 60% concentrate diet in which the grain mix consisted of either: 100% barley, 50% barley and 50% field peas, or 100% field peas for 42 d. As field pea inclusion increased, DMI increased, with calves fed field peas consuming a greater percentage of their body weight during both the first and second 21 d. Daily gains were not different, but G:F decreased slightly with field pea inclusion. Similarly, Anderson and Stoltenow (2004) again saw increases in DMI as field peas inclusion increased from 0 to 56% in a barley-based receiving diet. These increases in DMI in newly-weaned calves fed field peas may be due to the slower rate of ruminal starch fermentation of peas than of the barley being replaced. This may result in a lower incidence of subacute acidosis, allowing calves to reach higher intakes more quickly. In studies utilizing various pulse grains (legume crops harvested for their dry seed; for example: field peas, lentils, or chickpeas) to replace dry-rolled corn and canola meal in receiving diets, both Anderson and Schoonmaker (2004) and Gilbery et al. (2007) saw similar responses. Dry matter intake increased with increasing inclusion of the pulse grains, while ADG was greater than corn based controls, and G:F remained unchanged. Field pea grain appears to be useful for getting freshly-weaned calves up on feed.

Growing Diets. Field peas can be used as either a protein or energy source to replace a portion of other cereal grains in medium-concentrate growing diets, or as a supplement to cattle being wintered on hay alone. In a study by Fendrick et al. (2005b) using 0 to 26.3% field peas to replace corn in corn silage-based diets, DMI increased linearly with increasing field pea while ADG and G:F were unchanged. As Reed et al. (2004a) used field peas to replace dry-rolled corn in a 50% concentrate diet, OM, NDF, and ADF disappearance increased, proving to be an effective substitute for corn while potentially decreasing the need for protein supplementation. This improvement in digestibility over corn may be attributed to the lower starch content of field peas. This lower starch content may reduce the negative associative effects of starch on fiber digestion that are often observed in growing diets. However in another study, Soto-Navarro et al. (2004) found that as field peas increased from 0 to 45%, replacing soybean hulls, barley malt sprouts, and wheat middlings in a 45% hay diet, DMI and OMI decreased. Digestibility of DM, OM, and NDF were unaffected. Finally, Reed et al. (2004b) observed an increase in total DMI, but a decrease in forage DMI and total tract NDF disappearance when increasing levels of field peas were fed to steers consuming grass hay, and concluded that field peas acted similar to other cereal grains when supplemented in forage-based diets. These variable responses to field pea inclusion in growing diets appear to be at least partially due to variation in basal diet composition. Field peas appear to interact with the feedstuffs in various types of diets, depending on the characteristics of the basal diet, such as: starch content and availability, fiber content, and CP content and degradability.

Field Peas in feedlot diets

Optimum inclusion level. In this era of grain ethanol production, the supply of protein feeds has increased and become cheaper, while energy has become more expensive. Thus, cattle feeders have shifted their thinking and started to use high protein feeds to supply energy in finishing diets, in an effort to replace a portion of corn (Klopfenstein et al., 2008). Field peas could be viewed as one of these high-protein feeds, whose inclusion in diets has increased with their use as a replacement for other cereal grains.

The response in DMI by finishing cattle to increasing levels of field peas has been inconsistent. Fendrick et al. (2005a) fed 0, 20, 40, or 59% whole field peas to replace dry-rolled corn. A quadratic response was observed for DMI, with intake increasing up to 40% inclusion, then decreasing at 59%, but still remaining higher than that of cattle fed no peas. This intake response appears to disagree with Lardy et al. (2009), who observed either a linear decrease or no change in DMI when 0, 10, 20, or 30% dry-rolled peas replaced corn and a protein supplement, or when 0, 18, 27, or 36% peas replaced barley and barley sprouts. In another study, Jenkins et al. (2011) saw no differences in DMI when 10, 20, or 30% field peas replaced dry-rolled corn. This variation in DMI response to field pea inclusion may be due to differences in inclusion level and animal and basal diet variation. At low inclusions, field peas fill the role of a protein supplement, while at higher levels, peas replace other cereal grains as a source of fermentable starch. Field peas also interact with the other ingredients in the diet, as was discussed in growing diets.

This being said, all three studies that utilized increasing inclusions of field peas to replace other grains (Fendrick et al., 2005a; Lardy et al., 2009; Jenkins et al., 2011), observed no differences in ADG or G:F due to treatment. This is likely due to similar energy content, as field pea has been previously shown to have similar or greater NE_g than the corn that is being replaced. Loe et al. (2004) observed NE_g values for field peas that were 14% greater than that of corn when fed to finishing lambs. Similar or greater NE_g values for field peas relative to corn were also observed by Lardy et al. (2009) and Jenkins et al. (2011) when fed to finishing cattle. Only one study reviewed (Fendrick et al., 2005a) calculated the NE_g value for field peas in a high-concentrate finishing diet to be lower than that of corn. However, G:F was not affected by field pea inclusion in that study, so the energy value of peas in that particular situation is not clear and may have been underestimated.

Effect of processing. Processing, whether by rolling, ensiling, grinding, or steam flaking, has been shown to improve the metabolizable energy of various cereal grains (Owens et al., 1997). Because the previously discussed research has shown field peas to be suitable alternatives to other grains, it follows that further processing of field peas would also impact their feeding value. Birkelo et al. (2000) fed 10% whole or dry-rolled peas to replace whole corn and soybean meal. No differences in performance were observed due to either pea inclusion or degree of processing. However, Anderson et al. (2006) did observe a response to processing when field peas were included at 27% of a corn-based finishing diet as a protein and energy source. Heifers fed dry-rolled peas had greater DMI and ADG than those fed either whole or ground peas, with no differences in G:F. Perhaps the higher inclusion level of 27% was required to detect differences in performance due to processing. This response to processing has also been seen for corn grain and the mechanism for which was discussed above for creep feeding, where a diet containing dry-rolled peas may take advantage of an intermediate degree of processing where starch is available enough to optimize cattle performance, but not so much as to pose an acidosis risk.

Effects of peas on carcass characteristics. The majority of the research has observed no differences in carcass characteristics due to field pea inclusion in finishing diets. However, a few studies have observed differences in measures of carcass fatness. Lardy et al. (2009) found a quadratic increase in 12th rib fat thickness and either a tendency or a linear increase in marbling score in two experiments as field peas increased from 0 to 30% and 0 to 36% of the diet. In one of these experiments, the increase in fat thickness and marbling was accompanied by an increase in calculated NE_g of the diet. Jenkins et al. (2011) conducted a study that further examined the effects of field peas on carcass and sensory characteristics. As field pea inclusion increased from 0 to 30%, KPH increased quadratically, shear force values decreased linearly, and sensory tenderness and flavor ratings increased linearly. However, although no differences were detected for fat thickness or marbling in that study, field peas may have positive effects on meat quality attributes while maintaining similar growth performance.

Conclusion

Much time and energy have been invested in evaluating the replacement of high-priced corn with ethanol by-products in finishing diets. Condensed distillers solubles is one of the least-studied by-product feeds, but is possibly the by-product with the most potential for adding dietary energy and improving cattle performance at the lowest cost. Along with this approach of replacing grain with CDS, comes the need to investigate the upper limits of dietary fat and sulfur, when provided by CDS. A different type of alternative feed, but a replacement for corn nonetheless, is field pea grain. Like CDS, field peas are a regionally available and competitively priced feedstuff that has been shown to effectively replace a portion of corn while maintaining or improving feedlot performance. Yet, more work is needed to evaluate how field peas will perform in different types of finishing diets. Thus, the objectives of the following research are:

- To establish an optimum level of CDS inclusion in corn-based finishing diets.
- To evaluate the effects on cattle performance and rumen metabolism of feeding CDS in combination with other commonly fed by-products.
- To investigate the effects of replacing corn with field peas in diets containing WDGS, and to evaluate any interactions between the two feeds.

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Finishing performance and metabolism characteristics of feedlot cattle fed condensed distillers solubles[1]

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ABSTRACT

Three experiments evaluated the effects of condensed distillers solubles (CDS) on performance and metabolism characteristics in finishing diets. In Exp. 1, 250 crossbred steers (355 ± 18 kg of BW) were used in a randomized complete block design study and fed 0, 9, 18, 27, or 36% CDS to replace a portion of urea and a 1:1 ratio of dry-rolled corn (DRC) and high-moisture corn (HMC). Dietary fat increased from 3.7 to 9.4%, comparing 0 to 36% CDS. Intake decreased linearly ($P < 0.01$) as CDS increased. A quadratic response was observed for ADG ($P = 0.01$) with maximum gain calculated at 20.8% CDS, with all inclusions increased versus 0% CDS. A quadratic improvement in G:F was observed ($P < 0.01$) with a calculated maximum at 32.5% CDS, at which steers were 12% more efficient than those fed 0% CDS. Exp. 2 was a 5 × 5 Latin Square designed metabolism study evaluating the effects of feeding wet distillers grains plus solubles (WDGS) and CDS, both separately and in combination. Diets consisted of a DRC and HMC-based control, a 20% WDGS diet, a 27% CDS diet, and two diets with 20% WDGS plus either 8.5% CDS (LoMix) or 17% CDS (HiMix). Treatment had no effect on DM, OM, NDF, or fat digestibility ($P > 0.10$). Average ruminal pH was lower for steers fed CDS than for those fed WDGS alone ($P = 0.04$) and steers fed WDGS spent less time below pH 5.6 than steers fed diets with no WDGS ($P = 0.02$). Ruminal acetate concentration was lowest for 27CDS and HiMix diets ($P < 0.09$) and acetate to propionate ratio was numerically lowest for 27CDS and HiMix diets. Exp. 3 was a 2 × 4 factorial randomized complete block design study that evaluated effects of 0, 7, 14, and 21% CDS in diets containing 20% modified distillers grains plus solubles (MDGS) or 20% Synergy (a blend of wet corn gluten feed and MDGS) on performance of finishing cattle. A by-product × CDS interaction was observed for ADG, HCW, and final BW (*P* < 0.10). Average daily gain increased linearly (*P* = 0.01) and tended to increase quadratically (P = 0.09) in MDGS diets, with calculated maximum ADG occurring at 16% CDS inclusion. Inclusion of CDS had no effect on ADG in Synergy-based diets. A cubic effect of CDS level on DMI was observed (*P* = 0.01) and cattle fed Synergy tended to consume more DM than those fed MDGS (*P* = 0.06). Increasing CDS resulted in a linear increase in G:F (*P* < 0.01) regardless of basal by-product type. Condensed distillers solubles may be fed at inclusion levels higher than previously believed, both in corn-based diets and in combination with other by-product feeds.

Key words: by-products, condensed distillers solubles, fat

INTRODUCTION

Condensed distillers solubles (CDS), sometimes referred to as syrup, is the liquid that has been separated from the whole stillage that remains after ethanol distillation (Stock et al., 2000). The CDS is either added to distillers grains to produce distillers grains plus solubles or can be marketed and fed separately. The amount of CDS added to the grains is mostly dependent upon the ethanol plant's capacity to store the liquid CDS. When supply of CDS exceeds storage availability, it is available to livestock producers as a relatively inexpensive, yet energy-dense feed ingredient.

Limited data are available on including CDS in finishing diets, especially at relatively high levels (greater than 10% of diet DM). Rust et al. (1990) observed decreased DMI and improved G:F when steers consumed CDS at up to 20% diet DM. In two trials, Trenkle (2002, 2004) observed decreased or unchanged performance in finishing cattle consuming up to 8 or 12% CDS. However, because diets with up to 6.9% dietary fat from by-products have been fed with no detrimental effects on performance (Bremer, 2010), higher inclusions of CDS to provide this amount of fat may be acceptable. It stands to reason also that CDS and WCGF may be compatible feeds in the same way that WDGS and WCGF are, with complementary fat and fiber levels. In the only study including CDS in diets containing WCGF, Bremer (2010) found no differences in performance when up to 20% CDS was added to a 35% WCGF diet.

There may exist the opportunity to replace not only a portion of corn, but also a portion of higher-priced by-products with CDS in the finishing ration. Therefore, 3 experiments were conducted to determine an optimum inclusion of CDS when fed as the sole by-product in the diet, and to evaluate cattle performance and rumen metabolism when CDS is fed alone and in combination with other by-products.

MATERIALS AND METHODS

All animal care and management procedures were approved by the University of Nebraska-Lincoln Institutional Animal Care and Use Committee.

Exp. 1

Two-hundred fifty crossbred, backgrounded steer calves (355 ± 18 kg initial BW) were utilized in a randomized complete block designed, 132 d finishing trial. Cattle were received into feedlot pens and fed a common diet of Sweet Bran (Cargill Corn Milling, Blair, NE), cottonseed hulls, and alfalfa hay. Initial processing included vaccination with Bovi-Shield Gold 5 (a modified live virus vaccine for protection against: IBR, BVD Types I & II, PI3, and BRSV) and Somubac (for prevention of *Haemophilus somnus;*

Pfizer Animal Health, New York, NY), and injection with Dectomax (paraciticide; Pfizer Animal Health) and Micotil (antimicrobial; Elanco Animal Health, Greenfield, IN). Approximately 14 d later, cattle were revaccinated with Piliguard Pinkeye + 7 (for prevention of pinkeye and clostridial infections; Merck Animal Health, Summit, NJ) and Ultrabac-7 Somubac (*Haemophilus somnus* booster; Pfizer Animal Health) and fed a common diet of 85% Sweet Bran for 100 d until trial initiation. For 5 d before trial initiation, steers were limit fed the 85% Sweet Bran diet at 2.0% of BW and then weighed on d 0 and 1, the average of which was used as initial BW. Cattle were blocked into 3 blocks by d 0 BW, stratified by BW within block, and assigned randomly to pen. Light, medium, and heavy weight blocks consisted of 1, 3, and 1 reps, respectively. Pens were assigned randomly to 1 of 5 treatments with 10 steers per pen and 5 pens per treatment.

Treatments consisted of increasing levels of CDS (0, 9, 18, 27, and 36% of diet DM) replacing urea and a 1:1 blend of dry-rolled and high-moisture corn. Cattle were adapted to final experimental diets over 21 d, as alfalfa hay was decreased from 45% to 7.5% and corn increased, while CDS levels remained the same in both adaptation and finishing diets. All finishing diets contained 7.5% alfalfa hay and 5% dry supplement, which was formulated to provide 33 mg/kg and 90 mg/steer daily monensin and tylosin (Elanco Animal Health), respectively. Steers also received 130 mg thiamine daily. Soypass (Borregaard LignoTech, Sarpsborg, Norway) was included in all diets replacing corn from d 1 to d 40 to address an estimated metabolizable protein deficiency (NRC, 1996). Soypass (Borregaard LignoTech) decreased from 2.33% to 1.92% of the diet DM as CDS increased from 0 to 36%. Urea decreased from 1.58% in the 0% CDS diet to 0.35% in the 36% CDS diet. The CDS was received and analyzed by load throughout the study, was blended from two sources (Nebraska Energy LLC., Aurora, NE and Southwest Iowa Renewable Energy, Council Bluffs, IA), and contained 30.0% DM, 21.9% CP, 19.8% ether extract, and 1.1% sulfur. Dietary fat increased from 3.7 to 9.0%, whereas dietary sulfur increased from 0.12 to 0.48%, as CDS increased (Table 1).

Cattle were fed once daily at approximately 0800 and bunks were managed so only traces of feed remained at feeding time. Refused feed was removed from bunks as needed, weighed, and dried in a forced-air oven for 48 h at 60°C for DM determination. Samples of each feed ingredient were sampled weekly and analyzed for DM and also sampled weekly and composited by month for subsequent analysis. Ingredient CP and sulfur were analyzed using a combustion type N and S analyzer (TrueSpec N Determinator and TruSpec Sulfur Add-On Module, Leco Corporation, St. Joseph, MI). Ingredient ether extract was determined by a biphasic lipid extraction procedure as described by Bremer (2010). Briefly, sample is heated in a 1:1 mixture of hexane and diethyl ether for 9 h, dilute HCl is added, and sample is centrifuged to separate lipid layer from other liquid. Lipid layer is pipetted off, heated to drive off remaining solvent, and weighed.

Steers were implanted on d 1 with Revalor-S (Merck Animal Health) and treated with Phonectin pour-on (Teva Animal Health, St. Joseph, MO). All cattle were harvested on d 133 at Greater Omaha Pack (Omaha, NE). Hot carcass weight (HCW) and liver scores were recorded on d 133, while LM area, 12th rib fat thickness, and marbling score were collected after a 48-h chill. A constant KPH of 2.5% was assumed and used in the yield grade (YG) calculation of Boggs and Merkel (1993). A common dressing percent (63%) was used to calculate final BW, ADG and G:F from HCW. Live pen weights were captured on d 132 to calculate actual dressing percent. Data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). The model included block and treatment and pen was the experimental unit. Orthogonal contrasts were used to test the effects of CDS inclusion.

Exp. 2

Four-hundred crossbred steer calves (339 ± 15 kg initial BW) were utilized in a randomized complete block designed, 180-d finishing trial. Calves were received into feedlot pens and fed either RAMP (a complete-feed starter ration consisting of Sweet Bran and a small portion of alfalfa hay; Cargill Corn Milling, Blair, NE) or a traditional receiving diet. Initial processing was similar to Exp. 1, with the addition of a fenbendazole drench (Safeguard, Intervet) for internal parasite control. Re-vaccination protocol was also similar to Exp. 1. Cattle were limit-fed, weighed, and assigned to pen in the same manner as in Exp. 1, but only 2 weight blocks were used. The light and heavy weight blocks consisted of 1 and 4 reps, respectively. Pens were assigned randomly to 1 of 8 treatments with 10 steers per pen and 5 pens per treatment.

A 2 × 4 factorial arrangement of treatments was used (Table 2), with one factor being type of base by-product, either modified distillers grains plus solubles (MDGS; ADM, Columbus, NE) or a combination of modified distillers grains and wet corn gluten feed (Synergy; ADM, Columbus, NE) included at 20% of diet DM. The other factor was level of CDS (0, 7, 14, or 21% of diet DM). All by-products replaced a 1:1 blend of dry-rolled and high-moisture corn. Cattle were adapted to final experimental diets over 21 d, as alfalfa hay was decreased from 37.5% to 0% and corn increased, while all other ingredients remained constant. Urea was included at 0.51% of diet DM for the 0% CDS with Synergy and at 0.19% for the 7% CDS with Synergy diets only. All finishing diets contained 6% wheat straw and 5% dry supplement, which was formulated to provide 33 mg/kg monensin (DM basis, Elanco Animal Health) and 90 and 130 mg/steer daily tylosin (Elanco Animal Health) and thiamine, respectively.

Feed bunks were managed and ingredient samples collected and analyzed as described in Exp. 1. The CDS (BioFuel Ethanol Energy Corp., Wood River, NE) used in this experiment contained 35% DM, 24.4% CP, 7.3% NDF, 18.5% fat, and 0.97% S; MDGS contained 60% DM, 27.9% CP, 34.7% NDF, 10.5% fat, and 0.80% S; and Synergy contained 53% DM, 25.0% CP, 38.1% NDF, 8.1% fat, and 0.78% S.

Cattle were implanted on d 1 with Revalor-IS (Merck Animal Health) and on d 83 with Revalor-S (Merck Animal Health). Three steers died during the trial and were on the 21% CDS with 20% MDGS treatment, one of which was treated for polioencephalomalacia prior to death. All cattle were harvested on d 181 at Greater Omaha Pack (Omaha, NE). Carcass data were collected in the same manner as in Exp. 1.

Data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC). The model included block, by-product type, CDS level, and by-products type × CDS level. Orthogonal contrasts were used to test the effect of CDS inclusion level within each by-product type when an interaction occurred, or for the main effect of CDS when no interaction was observed. Pen was the experimental unit.

Exp. 3

Five ruminally cannulated, crossbred steers (440 ± 37 kg initial BW) were utilized in a 5 × 5 Latin Square designed, 90 d metabolism study. Steers were cannulated as calves, managed on pasture for approximately 160 d, and adapted to grain using WCGF before trial initiation. Steers were assigned to 1 of 5 balanced treatment sequences (Table 3). The control diet (CON) consisted of a 1:1 blend of dry-rolled and high-moisture corn with no added by-products. Condensed distillers solubles were added to the corn based diet at 27% (27CDS), an inclusion that was determined to be close to optimum in Exp. 1. Wet distillers grains were added to the corn diet at 20% (20WDGS), which is approximately the industry average inclusion of WDGS (Vasconcelos and Galyean, 2007). The final 2 diets had differing levels of CDS added to diets already containing WDGS: 8.5% CDS + 20% WDGS (LoMix) and 17% CDS + 20% WDGS (HiMix). The HiMix level of CDS was chosen so that diet would be isofat with 27CDS at roughly 7.4% dietary fat. All diets contained 7.5% alfalfa hay and 5% dry supplement, which was formulated to provide 33 mg/kg monensin (DM basis; Elanco Animal Health), and 90 and 130 mg/steer daily of tylosin (Elanco Animal Health), and thiamine, respectively. The CDS (BioFuel Ethanol Energy Corp., Wood River, NE) used in this study contained 36% DM, 23.8% CP, 7.9% NDF, 16.6% fat, and 1.34% S. The WDGS contained 35.4% DM, 31.5% CP, 34.7% NDF, 11.1% fat, and 1.22% S. Procedure for analysis of CDS and WDGS nutrients was the same as Exp. 1.

Steers were housed in individual, climate-controlled, concrete-floor pens, fed once daily at 0700 h, and allowed ad libitum access to feed and water. Refused feed was weighed and subsampled on d 14 to 18, composited, and later dried, ground, and analyzed for DM, OM, fat, and NDF. Feed ingredient samples were collected weekly, composited, and analyzed for DM, OM, CP, fat, NDF, and sulfur using procedures similar to Exp. 1, with the addition of NDF determination (Van Soest et al., 1991).

Period duration was 18 d with a 13 d adaptation period. Chromic oxide was dosed intraruminally (7.5g/dose) as an indigestible marker at 0700 and 1700 h on d 10 to 17. Fecal grab samples were collected 3 times/d on d 14 to 18, composited by day and frozen. Fecal samples were later dried in a 60°C oven for 72 h for DM determination, ground, and composited by period for OM, fat, and NDF. Fecal samples were analyzed for chromium concentration using the following procedure: digestion with 10 mL nitric acid and 3 mL peroxide with a hydrochloric acid addition, and analysis by Inductively Coupled Plasma (ServiTech Laboratories, Hastings, NE). Feed and fecal samples were ashed in a muffle furnace at 600°C for 6 h for OM determination. Rumen fluid was collected on d 18 at 0, 3, 6, 9, 12, and 15 h post-feeding, and frozen for a later volatile fatty acid (VFA) analysis using gas chromatography (Hewlett Packard 5890 Series II) according to the procedure of Erwin et al. (1961). Submersible wireless pH probes (Dascor, Inc., Escondido, CA) monitored rumen pH continuously, with data from d 12 to 18 being analyzed.

Intake, digestibility, and VFA data were analyzed as a Latin square design using the MIXED procedure of SAS (SAS Inst. Inc.). Fixed effects of treatment and period were included in the model. An unstructured covariance structure was used for VFA analysis with hour as a repeated measure. Ruminal pH data were analyzed as a crossover design using the GLIMMIX procedure of SAS (SAS Inst. Inc.). A compound symmetry covariance structure was used with day as a repeated measure. A Kenward-Rogers denominator degrees of freedom adjustment was utilized and steer was treated as a random effect for all analyses. Treatment differences were considered significant at $P < 0.10$.

RESULTS AND DISCUSSION

Exp. 1

As CDS level increased, DMI decreased linearly ($P < 0.01$; Table 4). Decreasing DMI is likely due to increased dietary fat and consequently increased energy density of the diets as CDS increased. In previous work, intake has consistently decreased or remained unchanged as fat supplementation increased, whether supplied by CDS or more traditional sources. Hatch et al. (1972) considered depressed DMI to be the most consistent effect of fat supplementation at 6 to 9% of diet DM. Rust et al. (1990) saw a 13.3% decrease in DMI when CDS containing 22.8% ether extract was fed at 20% of diet DM. Trenkle (2002) observed a linear decrease in DMI when CDS was included at 0, 4, or 8% of diet DM, but subsequently (Trenkle, 2004) saw no effect of up to 12% CDS on DMI. When fat was supplied by yellow grease, tallow, or blended animal-vegetable fat, DMI either decreased (Zinn, 1994; Zinn and Shen, 1996) or was not changed (Zinn 1989a). In contrast, a WDGS meta-analysis (Klopfenstein et al., 2008) found that DMI increased as inclusion of WDGS increased, up to 30% of diet DM. However, this increased intake in spite of increased dietary fat is likely due to a reduction in subacute acidosis due to the high NDF and low starch content of WDGS relative to corn.

Decreased DMI has been noted as one of the first signs of excessive sulfur content in high by-product diets (Sarturi et al., 2010). The 0.48% S level in the 36% CDS diet in this study may have been high enough to cause a decrease in DMI. However, no cattle in this study were observed with signs of polioencephalomalacia, and the decreased intake seen with increasing CDS is more likely due to increasing energy density of the diet.

A quadratic increase in ADG ($P = 0.01$) coupled with decreased DMI resulted in a quadratic increase in G:F ($P = 0.02$) as CDS inclusion increased. Calculated maximum ADG using the first derivative of the quadratic response occurred at 20.8% inclusion of CDS. Calculated maximum G:F occurred at 32.5% CDS, at which cattle were 12% more efficient than those fed 0% CDS. These improvements in ADG and G:F to increasing CDS are greater than previously reported by Trenkle et al. (2002, 2004) and suggest that much higher inclusions of CDS may be acceptable. These results are more characteristic of increasing WDGS inclusion (Vander Pol et al., 2005). It is interesting to note that G:F effectively plateaus at the highest inclusions of CDS, suggesting that perhaps even higher levels than were evaluated in the current study may be feasible. However, the limiting factor to inclusions greater than 36% CDS would likely be challenges in the handling properties of the diet and either dietary fat or sulfur or both.

Final BW and HCW increased quadratically ($P < 0.01$) as CDS inclusion increased. Cattle fed 18% CDS had 15 kg more HCW than those fed 0% CDS, with all cattle fed CDS having greater HCW than the control group. Dressing percent (data not shown) increased linearly ($P = 0.04$) as CDS inclusion increased. No other differences were observed for LM area, 12^{th} rib fat thickness, calculated YG, or marbling score, indicating that all cattle were harvested at a similar endpoint.

Exp. 2

A cubic effect of CDS level was observed for DMI ($P = 0.02$; Table 5). Dry matter intake was greatest at 14% CDS and lowest at 21% CDS in MDGS diets and overall, cattle fed Synergy tended to consume 1.9% more DM than those fed MDGS ($P = 0.05$).

A by-product × CDS level interaction was observed for ADG (*P* = 0.08). As CDS level increased in MDGS diets, ADG increased linearly (*P* = 0.01; Table 6) and tended to increase quadratically (*P* = 0.09). Average daily gain was greatest at 14% CDS and then decreased as CDS increased to 21% of diet DM. When optimum inclusion of CDS was calculated using the first derivative of the quadratic equation of the line in MDGS diets, ADG was maximized at 16% CDS. Average daily gain increased numerically in diets containing Synergy, with ADG being greatest at 21% CDS. Similarly to ADG, a by-product × CDS level interaction was observed for final BW (*P* = 0.09) and HCW (*P* = 0.09). As CDS level increased in MDGS diets, both final BW and HCW increased linearly (*P* = 0.01) and tended to increase quadratically (*P* = 0.10) up to 14% CDS, then decreased slightly as 21% CDS was added. Final BW and HCW increased numerically as CDS inclusion increased in Synergy diets (*P* > 0.22). This is in agreement with Bremer (2010), who found no differences in performance when up to 20% CDS was added to finishing diets containing 35% WCGF. Bremer (2010) also observed a drop in ADG, similar to the quadratic response in MDGS diets in the current study, when the highest levels of WDGS were added to 35% WCGF. However, those levels (26.7 and 40% WDGS) were greater than the 20% fed in the current study, and the authors hypothesized that the decreased performance was due to high dietary sulfur (up to 0.52%) in those diets. The depression in DMI and ADG observed in steers consuming 21% CDS added to diets containing 20% MDGS may be due to high dietary fat level (8.8%) of those diets, similar to the decreased ADG observed with 36% CDS in Exp.1.

Gain to feed increased linearly as level of CDS increased, regardless of by-product type (*P* < 0.01). The positive effect of increased dietary fat level on G:F has been well established (Zinn, 1989a; Brandt and Anderson, 1990; Ramirez and Zinn, 2000). Results of the current study are in agreement with Lodge et al. (1997), who observed improved G:F when fat (as CDS and tallow) was added to WCGF relative to WCGF alone. It is also interesting to note that CDS may be especially useful as a fat source that does not cause the depression in performance of other sources as observed by Vander Pol et al. (2009) and Bremer (2010).

No differences ($P > 0.12$; Table 5) due to by-product type or CDS level were observed for LM area, 12th rib fat thickness, marbling score, or calculated yield grade.

Exp. 3

One steer was removed from digestibility analysis due to apparent inaccurate chromium recovery in feces (Appendix 1). Data were then analyzed as a 4 × 5 Latin Rectangle. Post-trial analysis of feed ingredients confirmed that 27CDS and HiMix diets were approximately isofat (7.5 and 7.6% fat, respectively), thus providing the same amount of fat from either CDS only, or a blend of CDS and WDGS. No differences were observed in either DM or OM intake or apparent total tract digestibility among treatments ($P > 0.83$; Table 7). This differs from the results of Zinn (1989b), in which 4.9% and 8.1% dietary fat from tallow soap stock resulted in a linear decrease in OM digestibility relative to a no-added fat control. However, as in the current study, when comparable dietary fat (8.2%) was supplied by CDS (Bremer, 2010), DM digestibility was not different from the corn control. Dry matter digestibility was also unchanged compared to the control when 7.2% dietary fat was supplied by 40% WDGS (Vander Pol et al., 2009). These studies suggest that fat provided by CDS and other distillers by-products may not decrease digestibility, compared to traditional fat sources. Intake of NDF was greater for cattle consuming diets containing WDGS than for those fed CON and 27CDS ($P < 0.05$) due to the high NDF content of WDGS. Likewise, fat intake was greatest for cattle fed diets containing CDS and lowest for cattle fed CON, with those fed 20WDGS being intermediate. No differences in apparent total tract NDF or fat digestibility ($P > 0.36$) were observed among treatments. However, NDF digestibility was numerically greatest in diets containing WDGS, a frequently reported observation (Ham et al., 1994; Corrigan et al., 2009; Vander Pol et al., 2009; Bremer, 2010). Collectively, these data suggest that the traditional limits to fat supplementation indicated by decreased OM and NDF digestibility may not apply when fat is supplied by CDS or WDGS. Lipids in these by-product feeds do not appear to coat feed particles and inhibit cellulolytic activity as it is proposed that fats from tallow and vegetable and animal oils do (Zinn, 1989b).

Average ruminal pH was greatest for cattle fed 20WDGS, lowest for CON, and intermediate for those fed 27CDS and diets containing both CDS and WDGS ($P < 0.04$; Table 8). Steers fed CON and 27CDS diets spent more time with pH below 5.6 than those fed diets containing WDGS ($P < 0.05$). No differences were observed for minimum or maximum pH or pH magnitude or variance ($P > 0.10$). Ruminal acetate concentration was greatest for steers fed CON, 20WDGS, and LoMix diets and lowest for those fed 27CDS, with HiMix being intermediate ($P < 0.10$). While not significant, propionate concentration was numerically greatest and thus acetate:propionate ratio (A:P) was numerically lowest for steers fed 27CDS and HiMix diets (Table 8). These results are in agreement with those reported by Ham et al. (1994), who found that thin stillage and CDS reduced ruminal pH and increased propionate concentration, which the authors suggested may be due to reduced protozoal population. This is logical, as elevated dietary fat levels have also been reported to cause a reduction in protozoa (Zinn, 1989b). These results are also similar to those of Bremer (2010), in which steers fed 25.5% CDS had reduced ruminal pH and A:P when compared to those fed other fat sources. However, Rust et al. (1990) saw no change in ruminal pH or A:P when CDS was included in the diet, and Zinn (1989b) found no effect of increasing fat level on rumen pH. The reduced ruminal pH and A:P of steers fed 27CDS may also be related to their low NDF intake and digestibility, as explained by DiLorenzo and Galyean (2010). Fermentation of fiber is associated with increased A:P (Murphy et al., 1982), so it follows that diets containing CDS, with its low NDF content, would favor a decreased A:P.

Condensed distillers solubles may be fed in finishing diets at higher inclusions than previously believed while improving ADG and G:F. Inclusion of 27% CDS in DRC and HMC-based diets appears to be near optimal to maximize ADG and G:F. Slightly lower inclusions of up to 14 to 21% CDS may also be added to diets already containing either MDGS or Synergy, depending on composition of the basal by-product. Feeding CDS resulted in lower ruminal pH, decreased A:P ratio, and no statistical differences in nutrient digestibility.

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Table 1. Composition of diets (% of diet DM) fed to finishing steers (Exp. 1)

	Treatment[1]				
Item	0CDS	9CDS	18CDS	27CDS	36CDS
Dry-rolled corn	43.75	39.25	34.75	30.25	25.75
High-moisture corn	43.75	39.25	34.75	30.25	25.75
Condensed distillers solubles	-	9.00	18.00	27.00	36.00
Alfalfa hay	7.50	7.50	7.50	7.50	7.50
Dry supplement[2]					
Fine ground corn	1.585	1.841	2.120	2.378	2.634
Limestone	1.253	1.289	1.328	1.364	1.400
Urea	1.580	1.281	0.954	0.652	0.353
Soypass[3]	2.330	2.200	2.100	0.970	1.920
Salt	0.300	0.300	0.300	0.300	0.300
Tallow	0.125	0.125	0.125	0.125	0.125
Potassium chloride	0.049	0.057	0.065	0.072	0.080
Beef trace mineral[4]	0.050	0.050	0.050	0.050	0.050
Rumensin-80[5]	0.019	0.019	0.019	0.019	0.019
Vitamin A-D-E[6]	0.015	0.015	0.015	0.015	0.015
Thiamine[7]	0.014	0.014	0.014	0.014	0.014
Tylan-40[8]	0.010	0.010	0.010	0.010	0.010
Nutrient composition[9]					
CP	13.4	13.9	14.1	14.4	14.7
Ether extract	3.74	5.15	6.55	7.96	9.37
Sulfur	0.12	0.21	0.30	0.39	0.48

[1] 0CDS = 0% CDS diet, 9CDS = 9% CDS diet, 18CDS = 18% CDS diet, 27CDS = 27% CDS diet, 36CDS = 36% CDS diet.
[2] Supplement formulated to be fed at 5% of diet DM.
[3] Soypass was included in diets for d 1-40, replacing fine ground corn.
[4] Premix contained 10% Mg, 6% Zn, 4.5% Fe, 2% Mn, 0.5% Cu, 0.3% I, 0.05% Co.
[5] Premix contained 176 g of monensin·kg^{-1} (Elanco Animal Health, Greenfield, IN).
[6] Premix contained 1,500 IU of vitamin A, 3,000 IU of vitamin D, 3.7 IU of vitamin E·g^{-1}.
[7] Premix contained 88 g of thiamine·kg^{-1}.
[8] Premix contained 88 g of tylosin·kg^{-1} (Elanco Animal Health).
[9] Composition based on analyzed nutrients for each ingredient.

Table 2. Composition of diets containing 0, 7, 14, or 21% condensed distillers solubles (CDS) and either 20% modified distillers grains plus solubles (MDGS) or 20% Synergy[1] (% of diet DM) in Exp. 2.

	Treatment[2]							
	Synergy diets				MDGS diets			
Item	0CDS	7CDS	14CDS	21CDS	0CDS	7CDS	14CDS	21CDS
Dry-rolled corn	34.5	31.0	27.5	24.0	34.5	31.0	27.5	24.0
High-moisture corn	34.5	31.0	27.5	24.0	34.5	31.0	27.5	24.0
MDGS	-	-	-	-	20.0	20.0	20.0	20.0
Synergy	20.0	20.0	20.0	20.0	-	-	-	-
CDS	-	7.0	14.0	21.0	-	7.0	14.0	21.0
Wheat straw	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Dry supplement[3]								
Fine ground corn	2.249	2.562	2.763	2.763	2.763	2.763	2.763	2.763
Limestone	1.705	1.705	1.705	1.705	1.705	1.705	1.705	1.705
Urea	0.513	0.200	-	-	-	-	-	-
Salt	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300
Tallow	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
Beef trace mineral[4]	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Rumensin-90[5]	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017
Vitamin A-D-E[6]	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Thiamine[7]	0.017	0.016	0.016	0.016	0.016	0.016	0.016	0.016
Tylan-40[8]	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010

Nutrient Composition[9]								
CP	12.7	13.0	13.5	14.6	11.9	13.0	14.1	15.2
NDF	20.1	19.9	19.7	19.4	19.5	19.2	19.0	18.7
Ether extract	4.68	5.71	6.70	7.71	5.18	6.18	7.18	8.19
Sulfur	0.27	0.33	0.38	0.44	0.27	0.33	0.39	0.45

[1] Blend of modified distillers grains plus solubles and wet corn gluten feed (Synergy, ADM, Columbus, NE).

[2] 0CDS = 0% CDS plus 20% Synergy or MDGS, 7CDS = 7% CDS plus 20% Synergy or MDGS, 14CDS = 14% CDS plus 20% Synergy or MDGS, 21CDS = 21% CDS plus 20% Synergy or MDGS.

[3] Supplement formulated to be fed at 5% of diet DM.

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

[5] Premix contained 198 g of monensin·kg^{-1} (Elanco Animal Health, Greenfield, IN).

[6] Premix contained 1,500 IU of vitamin A, 3,000 IU of vitamin D, 3.7 IU of vitamin E·g^{-1}.

[7] Premix contained 88 g of thiamine·kg^{-1}.

[8] Premix contained 88 g of tylosin·kg^{-1} (Elanco Animal Health).

[9] Composition based on analyzed nutrients for each ingredient.

Table 3. Composition of diets (% of diet DM) fed to metabolism steers (Exp. 3).

	Treatment[1]				
Item	CON	20WDGS	27CDS	LoMix	HiMix
Dry-rolled corn	43.75	33.75	30.25	29.50	25.25
High-moisture corn	43.75	33.75	30.25	29.50	25.25
Alfalfa hay	7.50	7.50	7.50	7.50	7.50
Condensed distillers solubles	-	-	27.0	8.50	17.00
Wet distillers grains plus solubles	-	20.0	-	20.00	20.00
Dry supplement[2]					
Fine ground corn	1.848	3.240	3.240	3.240	3.240
Limestone	1.263	1.224	1.224	1.224	1.224
Urea	0.978	-	-	-	-
Salt	0.300	0.300	0.300	0.300	0.300
Potassium chloride	0.375	-	-	-	-
Tallow	0.125	0.125	0.125	0.125	0.125
Beef trace mineral[3]	0.050	0.050	0.050	0.050	0.050
Rumensin-90[4]	0.017	0.017	0.017	0.017	0.017
Vitamin A-D-E[5]	0.015	0.015	0.015	0.015	0.015
Thiamine[6]	0.019	0.019	0.019	0.019	0.019
Tylan-40[7]	0.011	0.011	0.011	0.011	0.011
Nutrient composition[8]					
CP	10.7	12.7	12.3	14.1	15.5
NDF	14.6	19.6	14.0	19.3	19.1
Ether extract	4.20	5.57	7.51	6.59	7.61
Sulfur	0.16	0.37	0.48	0.47	0.57

[1] CON = corn-based control diet, 20WDGS = 20% WDGS diet, 27CDS = 27% CDS diet, LoMix = 20% WDGS + 8.5%CDS diet, HiMix = 20% WDGS + 17% CDS diet.

[2] Supplement formulated to be fed at 5% of diet DM.

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

[4] Premix contained 198 g of monensin$\cdot kg^{-1}$ (Elanco Animal Health, Greenfield, IN).

[5] Premix contained 1,500 IU of vitamin A, 3,000 IU of vitamin D, 3.7 IU of vitamin E$\cdot g^{-1}$.

[6] Premix contained 88 g of thiamine$\cdot kg^{-1}$.

[7] Premix contained 88 g of tylosin$\cdot kg^{-1}$ (Elanco Animal Health).

[8] Composition based on analyzed nutrients for each ingredient.

Table 4. Performance and carcass characteristics of steers fed increasing levels of condensed distillers solubles in Exp. 1.

	Treatment[1]						*P*-value[2]	
Item	0CDS	9CDS	18CDS	27CDS	36CDS	SEM	Lin	Quad
Performance								
Initial BW, kg	354	354	354	355	355	1	0.24	0.85
Final BW, kg[3]	558	581	584	577	572	6	0.22	0.01
DMI, kg/d	10.3	10.3	10.3	10.0	9.6	0.2	<0.01	0.07
ADG, kg	1.55	1.71	1.74	1.68	1.65	0.04	0.25	0.01
G:F	0.151	0.166	0.169	0.168	0.172	0.003	<0.01	0.02
Carcass characteristics								
HCW, kg	352	366	367	363	360	4	0.22	0.01
12th-rib fat, cm	1.32	1.45	1.32	1.40	1.35	0.05	0.98	0.60
LM area, cm^2	79.4	81.3	82.6	80.0	80.6	1.3	0.76	0.29
Calculated YG[4]	3.37	3.44	3.30	3.42	3.35	0.08	0.80	0.94
Marbling score[5]	564	555	553	563	557	12	0.86	0.71

[1] 0CDS = 0% CDS diet, 9CDS = 9% CDS diet, 18CDS = 18% CDS diet, 27CDS = 27% CDS diet, 36CDS = 36% CDS diet.
[2] Lin = linear effect of CDS level, Quad = quadratic effect of CDS level.
[3] Calculated from HCW, adjusted to a 63% common dressing percent.
[4] YG = [2.5 + (6.35*fat thickness, cm) + (0.2*2% KPH) + (0.0017*HCW, kg) – (2.06*LM area, cm^2)]; (Boggs and Merkel, 1993).
[5] 400 = Slight[0], 500 = Small[0].

Table 5. Performance and carcass characteristics of steers fed 0, 7, 14, or 21% condensed distillers solubles (CDS) with 20% modified distillers grains plus solubles (MDGS) or 20% Synergy[1] in Exp. 2.

	Treatment[2]												
	Synergy diets				MDGS diets					P-value			
Item	0CDS	7CDS	14CDS	21CDS	0CDS	7CDS	14CDS	21CDS	SEM	By[3]	Int[4]	L[5]	Q[6]
Performance													
Initial BW, kg	349	348	349	348	348	348	348	348	0.9	0.46	0.99	0.59	0.93
Final BW, kg[7]	667	671	669	680	654	661	683	670	6.1	0.27	0.09	<0.01	0.49
DMI, kg/d[8]	11.3	11.2	11.2	11.0	11.0	10.8	11.4	10.6	0.16	0.05	0.16	0.27	0.14
ADG, kg	1.77	1.79	1.77	1.84	1.70	1.74	1.86	1.79	0.03	0.31	0.08	<0.01	0.48
G:F	0.157	0.160	0.159	0.168	0.155	0.162	0.163	0.169	0.003	0.48	0.67	<0.01	0.51
Carcass traits													
HCW, kg	420	423	421	429	412	416	430	422	3.9	0.27	0.09	<0.01	0.44
12th-rib fat, cm	1.40	1.45	1.42	1.50	1.32	1.45	1.50	1.50	0.05	0.95	0.64	0.04	0.56
LM area, cm^2	89.3	90.1	90.0	90.0	88.0	89.0	88.1	88.9	1.3	0.12	0.99	0.67	0.78
Calculated YG[9]	3.39	3.49	3.71	3.60	3.47	3.50	3.46	3.60	0.11	0.58	0.46	0.09	0.72
Marbling score[10]	583	570	570	567	583	586	561	580	13	0.50	0.70	0.29	0.45

[1] Blend of modified distillers grains plus solubles and wet corn gluten feed (Synergy, ADM, Columbus, NE).
[2] 0CDS = 0% CDS plus 20% Synergy or MDGS, 7CDS = 7% CDS plus 20% Synergy or MDGS, 14CDS = 14% CDS plus 20% Synergy or MDGS, 21CDS = 21% CDS plus 20% Synergy or MDGS.
[3] By = main effect of by-product type.
[4] Int = by-product × CDS level interaction.

[5] L = linear effect of CDS level.
[6] Q = quadratic effect of CDS level.
[7] Calculated from HCW, adjusted to a 63% common dressing percent.
[8] Cubic effect of CDS level on DMI (P = 0.02).
[9] YG = [2.5 + (6.35*fat thickness, cm) + (0.2*2% KPH) + (0.0017*HCW, kg) – (2.06*LM area, cm^2)]; (Boggs and Merkel, 1993).
[10] 400 = Slight^0, 500 = Small^0.

Table 6. Simple effect of increasing CDS level on diets containing 20% Synergy[1] or 20% modified distillers grains plus solubles (MDGS) in Exp. 2.

Item	CDS level, % diet DM				*P*-value	
	0	7	14	21	Lin[2]	Quad[3]
Synergy diets						
ADG, kg	1.77	1.79	1.77	1.84	0.17	0.52
Final BW, kg[4]	667	671	669	680	0.22	0.54
HCW, kg	420	423	421	429	0.22	0.53
MDGS diets						
ADG, kg	1.70	1.74	1.86	1.79	0.01	0.09
Final BW, kg	654	661	683	670	0.01	0.10
HCW, kg	412	416	430	422	0.01	0.10

[1] Blend of modified distillers grains plus solubles and wet corn gluten feed (Synergy, ADM, Columbus, NE).
[2] Lin = linear contrast for simple effect of CDS level.
[3] Quad = quadratic contrast for simple effect of CDS level.
[4] Calculated from HCW, adjusted to a 63% common dressing percent.

Table 7. Nutrient intake and total tract digestibility of metabolism steers fed condensed distillers solubles (CDS), wet distillers grains plus solubles (WDGS), or both in Exp. 3.

	Treatment[1]						
Item	CON	20WDGS	27CDS	LoMix	HiMix	SEM	*P*-value
Intake, kg/d							
DM	9.99	10.43	9.46	10.94	10.11	0.90	0.83
OM	9.60	9.92	8.94	10.33	9.57	0.86	0.84
NDF	1.31[a]	1.96[b]	1.18[a]	2.01[b]	1.94[b]	0.18	0.01
Fat	0.42[a]	0.58[a,c]	0.72[b,c]	0.72[b,c]	0.79[c]	0.07	0.02
Total tract digestibility, %							
DM	79.0	79.2	76.4	75.3	76.4	3.1	0.86
OM	80.4	80.7	78.8	77.2	78.5	2.9	0.91
NDF	44.9	51.3	35.1	50.9	49.5	7.7	0.46
Fat	91.3	87.7	88.7	74.6	84.8	5.8	0.36

[a-c] Means in a row with different superscripts are different (P < 0.05).

[1] CON = corn-based control diet, 20WDGS = 20% WDGS diet, 27CDS = 27% CDS diet, LoMix = 20% WDGS + 8.5%CDS diet, HiMix = 20% WDGS + 17% CDS diet.

Table 8. Ruminal pH parameters and VFA profile of metabolism steers fed condensed distillers solubles (CDS), wet distillers grains plus solubles (WDGS), or both in Exp. 3.

	Treatment[1]						
Item	CON	20WDGS	27CDS	LoMix	HiMix	SEM	*P*-value
Ruminal pH variable							
Average pH	5.26[a]	5.55[b]	5.34[a,c]	5.48[b,c]	5.31[a,c]	0.13	0.04
Maximum pH	6.06	6.22	6.10	6.33	6.13	0.13	0.34
Minimum pH	4.79	5.02	4.89	4.93	4.83	0.12	0.16
pH change	1.33	1.25	1.27	1.45	1.27	0.11	0.66
pH variance	0.10	0.07	0.08	0.10	0.07	0.02	0.43
Time < 5.6 min/d	1153[a]	885[b,c]	1170[a]	878[b,c]	1080[a,c]	120	0.02
Area < 5.6	667[b,c]	329[a]	488[a,c]	356[a]	508[a,c]	133	0.06
Time < 5.3, min/d	923	608	822	536	748	187	0.08
Area < 5.3	364	138	193	153	227	89	0.12
Ruminal VFA							
Total, mM	116.0	115.8	124.7	108.5	117.6	7.7	0.70
Acetate, mol/100 mol	50.9[a]	51.3[a]	47.0[b,c]	53.4[a]	49.7[a,c]	1.6	0.09
Propionate, mol/100 mol	33.9	35.5	36.9	28.8	36.8	3.0	0.31
Butyrate, mol/100 mol	9.7	8.8	8.8	11.9	11.5	2.2	0.78
Acetate:propionate	1.66	1.79	1.39	1.91	1.34	0.22	0.32

[a-c] Means in a row with different superscripts are different ($P < 0.10$).

[1] CON = corn-based control diet, 20WDGS = 20% WDGS diet, 27CDS = 27% CDS diet, LoMix = 20% WDGS + 8.5%CDS diet, HiMix = 20% WDGS + 17% CDS diet.

Appendix 1. Nutrient intake and total tract digestibility of steer 8427 in metabolism trial, removed from analysis due to apparent inaccurate chromium recovery; fed condensed distillers solubles (CDS), wet distillers grains plus solubles (WDGS), or both in Exp. 3.

	Treatment[1]				
Item	CON	20WDGS	27CDS	LoMix	HiMix
Intake, kg/d					
DM	10.42	11.72	9.94	7.98	12.39
OM	10.01	11.16	9.38	7.50	11.73
NDF	1.12	2.28	1.18	1.32	2.33
Fat	0.44	0.65	0.77	0.51	0.94
Total tract digestibility, %					
DM	63.9	61.2	82.0	62.9	68.1
OM	66.4	63.0	83.2	65.2	70.0
NDF	-12.8	-0.6	68.0	-10.4	25.0
Fat	80.3	78.0	87.2	78.9	82.5

[1] CON = corn-based control diet, 20WDGS = 20% WDGS diet, 27CDS = 27% CDS diet, LoMix = 20% WDGS + 8.5%CDS diet, HiMix = 20% WDGS + 17% CDS diet.

Effects of feeding field peas in finishing diets containing wet distillers grains plus solubles on cattle performance and carcass characteristics.[1]

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ABSTRACT

A finishing study was conducted to evaluate feeding field peas in corn-based diets with or without wet distillers grains with solubles (WDGS). Crossbred steers (n = 352, initial BW 356 ± 27 kg) were used in a randomized complete block design using a 2 × 2 factorial treatment structure. Cattle were blocked by initial BW, stratified by BW within block and assigned randomly to 32 pens and fed for 140 or 159 d. Pens were assigned randomly to 1 of 4 treatments with 8 pens/treatment. Factors consisted of 0 or 20% field peas and either 0 or 30% WDGS. Diets also contained 7.5% alfalfa hay and 6% supplement. There was a small (3 kg) difference in initial BW for the main effect of peas ($P = 0.04$), therefore initial BW was used as a covariate in the model. There was an interaction for DMI ($P < 0.01$). Feeding WDGS increased ADG by 0.3 kg/d ($P < 0.01$), while peas had no effect on ADG ($P = 0.33$). A peas × WDGS interaction was observed for G:F ($P < 0.01$), with WDGS increasing G:F by 12% in diets without peas ($P < 0.01$), but having no impact ($P = 0.12$) in diets containing peas. Feeding peas increased G:F ($P = 0.04$) in diets with no WDGS, but decreased G:F ($P = 0.03$) in the presence of WDGS. Feeding WDGS increased final BW and HCW ($P < 0.01$). A peas × WDGS interaction ($P = 0.01$) was observed for marbling score.

Keywords: distillers grains, feedlot, field peas

INTRODUCTION

Field pea production is increasing in the Northern Plains (NASS, 2009). Most of these peas are grown for the high-value human food market. However, the portion of the crop that does not meet quality standards for human consumption can be priced competitively enough to be utilized as a livestock feed. Additionally, in some regions, where there is not a large human food market for peas, farmers plant these nitrogen-fixing plants for both the agronomic benefits to fields and as an alternative feedstuff for livestock. Field peas are an attractive feed grain, as they are protein-dense with an energy value similar to corn (Loe et al., 2004). Previous research has focused on increasing inclusion of field peas in corn-based diets in which field pea inclusion has resulted in either no impact (Lardy et al., 2009 and Jenkins et al., 2011) or an increase (Flatt and Stanton, 2000) in G:F. To date, no research has evaluated the impact of combining field peas with grain milling co-products in finishing diets, even though the majority of cattle on feed (Vasconcelos and Galyean, 2007) are being fed diets that take advantage of the availability and relatively high feeding value of distillers grains (Klopfenstein et al., 2008). Thus, the objective of this study was to determine the effects of feeding field peas as a partial replacement for corn in diets that contain WDGS, and to evaluate whether the two feeds interact with one another.

MATERIALS AND METHODS

All animal care and management procedures were approved by the University of Nebraska-Lincoln Institutional Animal Care and Use Committee.

Three hundred fifty-two crossbred yearling steers (initial BW = 356 ± 27 kg) were utilized in a randomized complete block designed finishing trial at the UNL Panhandle Research and Extension Center Feedlot located near Scottsbluff, Nebraska. Cattle were sourced from multiple area ranches and fed a common 50% grass hay, 50% WDGS and dry-rolled corn diet until trial initiation. Steers were limit-fed at 2.0% of BW for 5 d before trial initiation and then weighed on d 0 and 1, the average of which was used as initial BW. Cattle were blocked by d 0 BW, stratified by BW within block, and assigned randomly to pen. Pens were assigned randomly to 1 of 4 treatments with 11 steers per pen and 8 pens per treatment. Light and heavy blocks had 2 reps per treatment while the medium block had 4. Initial processing on d 0 included vaccination with Bovi-Shield Gold 5 (a modified live virus vaccine for the prevention of: IBR, BVD Types I & II, PI3, and BRSV; Pfizer Animal Health, New York, NY) and Vision-7 (for the prevention of Clostridium chauvoei, septicum, novyi, sordellii, perfringens Types C & D and Moraxella bovis; Merck Animal Health, Summit, NJ) and treatment with ivermectin pour-on paraciticide (Ivomec; Merial, Duluth, GA). A 2 × 2 factorial arrangement of treatments was used with one factor being 0 or 20% whole field peas, the other factor being 0 or 30% corn wet distillers grains plus solubles (WDGS; Table 1). All finishing diets were based on dry-rolled corn (DRC) and contained 7.5% alfalfa hay and 6.0% liquid supplement (DM basis) which was formulated to provide 33 mg/kg monensin (Rumensin, Elanco Animal Health, Greenfield, IN) and 90 mg/steer daily tylosin (Tylan, Elanco Animal Health). Alfalfa hay was gradually replaced by DRC in 5 steps during a 21-d adaptation period. Inclusions of field peas at 20% and WDGS at 30% remained constant during each step.

Cattle were fed once daily at approximately 0800 and bunks were managed so only traces of feed remained at feeding time. Refused feed was removed from bunks as needed, weighed, and dried in a forced-air oven for 48 h at 60°C for DM determination (AOAC Method 935.29). Samples of each feed ingredient were sampled weekly and analyzed for DM and also sampled weekly and composited by month for subsequent analysis and calculation of dietary CP, fat, NDF, and sulfur. The nutrient composition (DM basis) of the field peas used in this study was: 89.6% DM, 23.4% CP, 14.0% NDF, 1.2% crude fat, 49.7% starch, and 0.24% sulfur. The WDGS used in this study was (DM basis): 33.1% DM, 30.9% CP, 37.4% NDF, 10.9% crude fat, and 0.52% sulfur. Feed ingredients were analyzed according to the following procedures: DM, CP (AOAC Method 990.03), crude fat (AOAC Method 920.39), NDF (Ankom Technology, Fairport, NY), starch (Xiong, et al., 1989), and sulfur (AOAC Method 968.08).

Cattle were implanted with Revalor-XS (Merck Animal Health) on d 1. Cattle in light weight blocks were harvested on d 141, with the remainder harvested on d 160 at Cargill Meat Solutions (Fort Morgan, CO). Carcass data were collected by Diamond T Livestock Services (Yuma, CO). Hot carcass weight (HCW) and liver scores were recorded on day of slaughter, while LM area, 12^{th} rib fat thickness, and marbling score were collected after a 48-h chill. A constant KPH of 2.5% was assumed and used in the yield grade (YG) calculation of Boggs and Merkel (1993). A common dressing percent (63%) was used to calculate final BW, ADG and G:F from HCW. Individual live final BW was collected by feedlot personnel on d 140 and 159 and shrunk 4% to calculate dressing percent.

Data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC) as a 2 × 2 factorial with pen as the experimental unit. The model included the fixed effects of block, peas, WDGS, and the peas × WDGS interaction. If a significant interaction was not detected ($P > 0.05$), main effects were analyzed. In cases of a significant interaction, simple effects were presented and discussed. There was a small (3 kg) significant difference in initial BW for the main effect of peas, so initial BW was used as a covariate in the model. Differences were considered significant at $P < 0.05$.

RESULTS AND DISCUSSION

A significant peas × WDGS interaction ($P < 0.01$; Table 2) was observed for DMI, in which WDGS had no effect ($P = 0.07$) on DMI in diets with no peas, but increased DMI by 1.2 kg in diets containing peas ($P < 0.01$). Inclusion of peas decreased DMI by 0.6 kg in diets with no WDGS ($P < 0.01$), but had no effect ($P = 0.10$) on DMI in diets containing WDGS. The impact of field pea inclusion on DMI in finishing diets has been mixed. In agreement with the current study, decreases in DMI due to pea inclusion have been observed by Lardy et al. (2009), when peas replaced a combination of dry-rolled corn, high-moisture corn, and canola meal, and by Flatt and Stanton (2000), when peas replaced whole corn. No change in DMI due to pea inclusion was observed by Loe et al. (2004) in lamb finishing diets, Lardy et al. (2009) in both dry-rolled corn and barley based diets, and Jenkins et al. (2011) in dry-rolled corn diets. Conversely, Fendrick et al. (2005) observed an increase in DMI at up to 40% inclusion of peas, but then a decrease at 59% of dietary DM when replacing dry-rolled corn, and Anderson (1999) observed an increase in DMI when peas replaced dry-rolled barley.

Similar to previous field pea research (Lardy et al., 2009; Jenkins at al., 2011), feeding peas had no effect on ADG ($P = 0.33$). As expected, WDGS improved ADG ($P < 0.01$), which is a common observation (Klopfenstein et al., 2008). A significant peas × WDGS interaction ($P < 0.01$) was observed for G:F, with WDGS increasing G:F by 12% in diets without peas ($P < 0.01$), but having only a tendency ($P = 0.12$) to improve G:F in diets containing peas. In the current study, feeding peas increased G:F (*P* = 0.04) in diets with no WDGS, similar to the observation of Flatt and Stanton (2000), but decreased G:F (*P* = 0.03) in the presence of WDGS. However, more often, there has been no effect of peas on G:F (Fendrick et al., 2005; Lardy et al., 2009; Jenkins et al., 2011). While all cattle fed field peas or WDGS or both were more efficient than those fed the corn control, feeding both 20% peas and 30% WDGS together did not result in an additive response, but rather, the performance of those cattle was intermediate to cattle fed only one or the other feedstuff. One hypothesis for this lack of an additive response is that by replacing corn in 50% of the diet DM with peas and WDGS, too much starch was replaced. It is widely accepted that starch is the main energy component of cereal grains, and that grains increase energy density of the diet (Huntington, 1997). So, in an effort to replace expensive corn with other feeds, some of which are lower in starch, cattle performance may be reduced. There is evidence to suggest that there is an associative response to adding even a small amount of corn to finishing diets. Rich et al. (2011) fed diets containing up to 85% WDGS with no corn and up to 77% WDGS with 8.4 to 85% dry-rolled corn included in the diet. All cattle fed diets containing corn had improved ADG and G:F when compared to those fed no corn. In a study by Zinn et al. (1997), ADG and G:F also decreased as steam flaked corn inclusion decreased to 41.9% of diet DM as cottonseed meal increased to 32%. These studies show decreased performance when relatively large amounts of corn are replaced by feeds that are lower in starch. The field peas fed in the current study contained 31% less starch and 59% less fat than the DRC being replaced, while corn inclusion decreased to 36.5% of diet DM. Thus, the differences in G:F may be a function of dietary energy density. This appears to disagree with the previous work of Loe et al. (2004), who found the NEg value of field peas to be similar to that of corn, and the study by Lardy et al. (2009), in which a quadratic increase in diet NEg was observed as field pea inclusion increased. However, Fendrick et al. (2005) calculated lower NEg values for field peas relative to corn at each inclusion level evaluated, up to 59% of diet DM. These differences in G:F response to increasing field pea inclusion are likely due to variation in nutrient content of field pea variety fed, and variation in the nutrient composition of the basal diets being evaluated.

A significant peas × WDGS interaction ($P = 0.01$) was observed for marbling score. Feeding WDGS decreased marbling score when peas were not included in the diet, but increased marbling score in the presence of peas. However, the magnitude of these differences was small, with cattle in all treatments averaging USDA Choice quality grade. The inclusion of 20% field peas had no impact ($P > 0.30$) on other carcass characteristics. The inclusion of 30% WDGS increased final BW, HCW, dressing percent, 12^{th} rib fat depth, and calculated yield grade ($P < 0.01$). These results agree with the common observation that cattle fed WDGS gain more rapidly, and thus are fatter at equal days on feed (Klopfenstein et al., 2008).

IMPLICATIONS

Field peas can be utilized as a replacement for a portion of the corn in finishing diets. Inclusion of 20% field peas improved G:F by 4% in corn-based diets. Even though the positive impact of WDGS on G:F was slightly diminished in the presence of 20% field peas, performance was acceptable when 50% corn was replaced with a combination of field peas and WDGS.

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Table 1. Composition of diets (% of diet DM) containing 0 or 20% field peas and 0 or 30% wet distillers grains plus solubles (WDGS).

	Treatment[1]			
	0 Peas		20 Peas	
Item	0WDGS	30WDGS	0WDGS	30WDGS
Dry-rolled corn	86.5	56.5	66.5	36.5
Field peas	-	-	20.0	20.0
WDGS	-	30.0	-	30.0
Alfalfa hay	7.5	7.5	7.5	7.5
Supplement[2]				
Urea	1.07	-	0.40	-
Limestone	1.34	1.34	1.34	1.34
Potassium chloride	0.30	-	-	-
Salt	0.300	0.300	0.300	0.300
Rumensin-90[3]	0.016	0.016	0.016	0.016
Tylan-40[4]	0.009	0.009	0.009	0.009
Nutrient composition[5]				
DM	85.2	57.6	85.6	57.8
CP	11.5	15.2	12.6	18.2
NDF	10.7	19.7	12.0	21.0
Crude fat	2.77	5.08	2.39	4.70
Sulfur	0.14	0.25	0.16	0.27

[1] 0WDGS = 0% WDGS plus 0 or 20% field peas, 30WDGS = 30% WDGS plus 0 or 20% field peas.
[2] Liquid supplement formulated to be fed at 6% diet DM, to provide: 50 ppm Fe, 30 ppm Zn, 20 ppm Mn, 10 ppm Cu, 0.5 ppm I, 0.1 ppm Co, 0.1 ppm Se, 1000 IU Vit. A, 125 IU Vit. D, 1.5 IU Vit. E.
[3] Premix contained 176 g of monensin$\cdot$kg^{-1} (Elanco Animal Health, Greenfield, IN).
[4] Premix contained 88 g of tylosin$\cdot$kg^{-1} (Elanco Animal Health).
[5] Composition based on analyzed nutrients for each ingredient.

Table 2. Performance and carcass characteristics of steers fed 0 or 20% field peas and 0 or 30% wet distillers grains plus solubles (WDGS).

	Treatment[1]							
	0 Peas		20 Peas			*P*-value		
Item	0WDGS	30WDGS	0WDGS	30WDGS	SEM	Peas[2]	WDGS[3]	Int.[4]
Performance								
Initial BW, kg	358	357	355	355	1.0	0.04	0.77	0.48
Final BW, kg[5]	635	677	632	672	8.0	0.32	<0.01	0.83
DMI, kg	11.3^{b}	$11.6^{b,c}$	10.7^{a}	11.9^{c}	0.3	0.30	<0.01	<0.01
ADG, kg	1.87	2.15	1.85	2.12	0.05	0.33	<0.01	0.82
G:F	0.165^{a}	0.185^{c}	0.172^{b}	$0.177^{b,c}$	0.002	0.96	<0.01	<0.01
Live final BW, kg	675	640	663	639	6.1	0.33	<0.01	0.33
Carcass traits								
HCW, kg	400	427	398	424	5.1	0.33	<0.01	0.80
Dressing %	62.4	63.5	62.2	63.5	0.01	0.60	<0.01	0.52
Marbling score[6]	591^{a}	$574^{a,b}$	566^{b}	591^{a}	8.5	0.30	0.72	0.01
LM area, cm^2	85.3	85.6	84.9	84.6	0.76	0.37	1.0	0.66
12th-rib fat, cm	1.52	1.65	1.52	1.70	0.01	0.40	<0.01	0.25
Calculated YG[7]	3.54	3.86	3.51	3.95	0.046	0.54	<0.01	0.24

$^{a-c}$ Means with different superscripts are different ($P < 0.05$).

[1] 0WDGS = 0% WDGS plus 0 or 20% field peas, 30WDGS = 30% WDGS plus 0 or 20% field peas.

[2] Peas = Main effect of field pea inclusion.

[3] WDGS = Main effect of WDGS inclusion.
[4] Int. = field peas × WDGS interaction.
[5] Calculated from HCW, adjusted to a 63% common dressing percent.
[6] 400 = $Slight^0$, 500 = $Small^0$.
[7] YG = [2.5 + (6.35*fat thickness, cm) + (0.2*2% KPH) + (0.0017*HCW, kg) – (2.06*LM area, cm^2)]; (Boggs and Merkel, 1993)