EFFECTS OF THE PROPORTION OF SUPPLEMENTAL DIETARY CRUDE PROTEIN SUPPLIED BY UREA ON PERFORMANCE AND CARCASS CHARACTERISTICS OF FINISHING BEEF CATTLE FED STEAM-FLAKED CORN-BASED DIETS WITH SWEET BRAN® WET CORN GLUTEN FEED

by

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TABLE OF CONTENTS

ABSTRACT

An experiment was conducted to examine the effects of urea level in steam-flaked corn-based diets containing 25% (DM basis) Sweet Bran® wet corn gluten feed (WCGF) on performance and carcass characteristics of beef steers. British x Continental steers were blocked by BW (average initial BW = 402.76 kg ± 10.75; n = 240) and assigned to one of three dietary treatments, which consisted of three different ratios (N basis) of urea:cottonseed meal provided in the supplemental CP: (1) 33%urea:67% cottonseed meal **(33%)**; (2) 67% urea:33% cottonseed meal **(67%)**; and (3) 100% urea:0% cottonseed meal **(100%)**. Eight pens per treatment were arranged in a randomized complete block design. Performance and carcass data were analyzed using mixed model procedures of SAS (SAS Institute, Cary, NC), with pen designated as the experimental unit and block as the random effect. There was a quadratic (P = 0.06) effect of the proportion of urea in supplemental CP on ADG from d 0 to 56, as steers fed the 33% diet gained less than cattle fed either the 67 or 100% treatment. From d 0 to 112, ADG increased linearly (P = 0.09) with increasing proportion of urea provided in the supplement. For the overall feeding period, but especially early in the feeding period, ADG was numerically greatest in the steers fed the diet with 67% urea:33% cottonseed meal. Average daily DM intake (DMI) was affected linearly (P = 0.001), by urea level, as cattle fed the 33% treatment consumed less than those fed the 67 or 100% treatments from d 0 to 28. For the entire feeding period, DMI tended (P = 0.14) to increase linearly with increasing proportion of urea. There was a quadratic effect on gain:feed ratio from d 0 to end; steers fed the diet containing 67% urea:33% cottonseed meal gained more efficiently (P = 0.09) than those fed the 33% diet, whereas gain:feed by steers fed the 100% treatment did not differ from that of steers in the other two treatments. Furthermore, there was a tendency for a quadratic effect (P = 0.14) of urea level relative to hot carcass weight (HCW). Average HCW was 393.0 kg for the 67% treatment, whereas the 33% treatment averaged 384.3 kg, with an intermediate value of 390.5 kg for the 100% treatment. Percentage of internal fat was least (P = 0.10, linear effect of urea level) for the 33% diet. There were no treatment effects for yield grade, dressing percent, percentage of cattle grading USDA Choice, marbling score, backfat thickness, or longissimus muscle area. Incidence of liver abscess did not differ (P = 0.30) among the three treatments; however, the 33% treatment had a numerically higher rate (12.25%) than the 67% (8.26%) and the 100% (7.50%) treatments. Results indicate that when feeding a finishing diet based on steam-flaked corn that contains 25% (DM basis) Sweet Bran® WCGF, providing supplemental CP with a ratio of at least 67% urea:33% cottonseed meal improves ADG and feed efficiency compared with 33% urea:67% cottonseed meal.

LIST OF TABLES

CHAPTER I

INTRODUCTION

Wet corn gluten feed (WCGF) is a significant by-product of the corn milling industry that is becoming increasingly common in commercial feedlot diets. Several advantages are available to the producer who includes appropriate amounts of WCGF in beef cattle diets. Wet corn gluten feed has been reported to be comparable in net energy concentration to dry-rolled corn (Ham et al., 1995). Therefore, a less expensive feed by-product ingredient such as wet corn gluten feed can decrease associated feed costs to the producer without sacrificing the energy content of the diet or animal performance (Sindt et al., 2002). Furthermore, WCGF is a fibrous feed ingredient, and research has demonstrated a significant decrease in digestive disorders of beef cattle offered diets containing WCGF versus high-concentrate corn-based diets (Krehbiel et al., 1995). By including WCGF in the diet, it may be possible to decrease ruminal acidosis by increasing the level of fiber and decreasing the amount of starch digested in the rumen. Other issues such as cost, availability, and consistency of traditional roughage sources may further enhance the role of wet corn gluten feed as an important feed ingredient in today's beef cattle diets.

Protein requirements in beef cattle have been cause for recent debate among animal scientists. The National Research Council (NRC) is the primary source for nutrient requirements of beef cattle. The most recent NRC publication (NRC, 1996) separates intake protein requirements into two categories: ruminally degraded (DIP) and ruminally undegraded protein (UIP). This system is commonly referred to as the metabolizable protein (MP) system. Although this system seems to be the most suitable method available in determining beef cattle protein requirements, there has been some debate about the level of DIP required with various types of diets. Wet corn gluten feed contains approximately 23% CP, of which a majority is available in the form of DIP, but the optimal level of DIP needed in diets containing WCGF fed to beef cattle has not been adequately determined. Therefore, the objective of this study was to determine the effects of the proportion of supplemental dietary crude protein supplied by urea (a source of DIP) on feedlot performance and carcass characteristics of beef cattle fed a high-concentrate diet based on steam-flaked corn plus 25% (DM basis) Sweet Bran® wet corn gluten feed.

CHAPTER II

REVIEW OF LITERATURE

Wet Corn Gluten Feed

Wet corn gluten feed (WCGF) is a fibrous by-product of the corn wet milling industry, and supplies of this feed ingredient are readily available because of increasing demand for ethanol-containing products, as well as fructose for corn sweeteners. Wet corn gluten feed comprises a mixture of primarily the high-fiber corn hull plus steepwater solubles, a molasses-like residue from the corn steeping process. The energy content of WCGF has been reported to be similar to that of dry-rolled corn (Ham et al., 1995), with the primary difference being the level of starch content (22.5 vs. 72%). One advantage of including WCGF in the diet may be the ability to decrease the incidence of subacute acidosis by providing a highly digestible fiber source (Firkins et al., 1985; Krehbiel et al., 1995), with little or no compromise in cattle performance (Hussein and Berger, 1995). Wet corn gluten feed also contains a substantial fraction (22 to 24%) of crude protein (CP), the majority of which is ruminally degraded intake protein (DIP; NRC, 1996). It is not certain whether cattle fed WCGF require less supplemental DIP (e.g., urea). Likewise, the requirement for supplemental undegraded intake protein (UIP; NRC, 1996), or metabolizable protein may be increased, particularly in lightweight calves fed growing diets that include WCGF.

Growing and Finishing Performance

Wet corn gluten feed has been reported to have a NEg content similar to corn (Ham et al., 1995), and cattle fed moderate amounts of WCGF have demonstrated increased performance (Larson et al., 1993). Therefore, WCGF may provide an economic advantage when it replaces corn in beef cattle growing and finishing diets.

Richards et al. (1998) conducted two trials to evaluate the effects of WCGF, supplemental protein, and tallow compared to a standard dry-rolled corn (DRC) diet. In Trial 1, crossbred steer calves were blocked by body weight (BW) and randomly assigned to one of four treatments. Wet corn gluten feed replaced DRC, molasses, and a portion of the supplement at 0, 25 (two diets), or 50% of the dietary DM. The 0%, and one of the 25% treatments included a protein supplement consisting of 50% urea, 25% soybean meal, and 25% of an 80:20 ratio of feather meal and blood meal. The other 25% treatment included a protein supplement containing 100% urea, and the 50% WCGF treatment did not receive any additional protein. Steers fed either of the 25 or the 50% WCGF treatment had increased ($P < 0.10$) average daily gain (ADG) compared with the DRC control; however, there were no significant differences among treatments observed for dry matter intake (DMI). Steers fed the 25% WCGF diet plus the combination protein sources, as well as those fed the 50% WCGF diet were more efficient ($P < 0.10$) than steers fed the DRC control diet. The 25% WCGF treatment plus urea had a tendency ($P = 0.14$) for increased feed efficiency compared with the DRC control. The authors suggested that the observed increase in efficiency and ADG may have resulted from a decrease in subacute acidosis. Degraded intake protein (DIP) was least in the DRC control diet, intermediate for the 25% WCGF, and greatest in the 50% WCGF treatment ($P < 0.10$).

In Trial 2 (Richards et al., 1998), yearling steers were blocked by BW and assigned randomly to one of four treatments in a 2 x 2 factorial arrangement. Wet corn gluten feed replaced 0 or 50% of the DRC and molasses-urea supplement. Diets were then fed with or without 3% added tallow. Steers fed the 50% WCGF diets had greater ($P < 0.10$) ADG, and feed efficiency ($P < 0.01$) than steers fed DRC or 0% WCGF diets. Additionally, steers fed diets that included 3% tallow were more efficient ($P < 0.05$), and gained faster ($P < 0.05$) than those without added fat. Intake of DIP exceeded requirements (NRC, 1996) for all treatments, and was higher ($P < 0.01$) for WCGF diets than for DRC diets.

Larson et al. (1993) replicated consecutive years of both yearling and calf finishing trials to evaluate the feeding value of wet distillers by-products (WDB). In the yearling trial, steers were allotted randomly to dietary treatments consisting of 0 (control), 5.2, 12.6, or 40.0% (DM basis) of WDB. For the control diet supplemental protein was provided with a 50:50 ratio of SBM and urea. Crude protein provided by the 5.2 and 12.6% WDB diets replaced equivalent amounts of CP supplied by SBM in the control diet. The 40% WDB provided sufficient CP to replace the entire SBM and urea supplement, in addition to a portion of the corn. Therefore, the 40% WDB diet was projected to use WDB as both a protein and energy source. There was no year x trial interactions ($P > 0.10$) among WDB levels; therefore, data were pooled across years.

There was a quadratic ($P = 0.04$) response observed for ADG; ADG increased with increasing dietary level of WDB until reaching a plateau, such that the 12.6 and 40.0% WDB treatments had equal ADG (1.76 kg/d) for the entire feeding period. Dry matter intake decreased ($P < 0.01$) linearly as dietary level of WDB increased, and feed efficiency increased ($P < 0.01$) as level of WDB increased.

For the calf trial, Larson et al. (1993) used identical treatments to the yearling trial, with the exception of the control protein supplement. In the calf trial, SBM was the sole source of protein supplementation, as opposed to the 50:50 ratio of SBM and urea in the yearling trial. Again, no interactions ($P > 0.10$) were detected with years and data were pooled across years. Response to WDB level was similar for the calves and yearlings. Calves fed increased levels of WDB had greater ADG ($P < 0.01$), decreased DMI ($P < 0.01$), and gain:feed was greater ($P < 0.01$) as WDB level increased. Quality grade increased linearly ($P < 0.01$) as WDB levels increased.

Averaged over the yearling and calf trials (Larson et al., 1993), cattle fed WDB consumed less starch, but more NDF and fat compared to the control treatments. Wet distillers by-products provided 80, 62, and 47% greater NEg than corn when fed to yearlings, and 17, 33, and 29% greater NEg when fed to calves at the 5.2, 12.6, and 40.0% level, respectively. The authors suggested three factors that likely contributed to the greater energy value of WDB. First, WDB contained over three times greater fat content than corn. Second, ethanol provided by WDB was rapidly absorbed and metabolized to acetate for energy utilization. Blaxter (1989) reported ethanol to contain 7.1 Mcal/kg of gross energy, versus 4.2 Mcal/kg in starch. Third, cattle fed WDB might have benefited from the decreased level of starch intake. A decrease in starch intake might correspond to a decreased occurrence of subacute acidosis, thereby decreasing the associated negative effects on gain and efficiency (Stock et al., 1990). Overall, Larson et al. (1993) concluded that finishing cattle fed up to 40% (DM basis) WDB have improved efficiency compared with traditional corn-based diets.

Parsons et al. (2001) investigated the effects of Sweet Bran® corn gluten feed and different levels of roughage fed to finishing beef steers. Four dietary treatments were evaluated to compare a standard (STD) steam-flaked corn-based finishing diet (9% alfalfa hay in the DM) to diets containing 40% (DM basis) Sweet Bran and either 0, 4.5, or 9% alfalfa hay (DM basis). Crossbred cattle were blocked by BW and assigned randomly to one of the four previously mentioned treatments. The DMI was approximately 0.23 kg less ($P < 0.05$) per steer for the STD diet vs. the average of the Sweet Bran diets. No differences ($P > 0.05$) were detected in ADG or feed:gain ratio when comparing the STD diet to the average of the Sweet Bran diets; however, several significant differences were detected within the Sweet Bran diets. There was a linear increase in final BW ($P < 0.02$), ADG ($P < 0.01$), and DMI ($P < 0.01$) associated with increasing roughage level. When carcass data were evaluated, again a linear effect ($P < 0.01$) of roughage level within Sweet Bran diets was recorded for hot carcass weight. Additionally, a quadratic response ($P < 0.03$) in roughage level within Sweet Bran diets was detected for fat thickness and yield grade, as well as dressing percent ($P < 0.05$), with highest values observed in the 4.5% alfalfa hay diet. These data suggest that adding alfalfa hay to diets containing Sweet Bran wet corn gluten feed may increase ADG, DMI, and HCW.

Montgomery et al. (2003) performed a similar study to Parsons et al. (2001) with increasing amounts of alfalfa hay in 40% WCGF diets limit-fed to growing steers. Addition of alfalfa hay in the diet resulted in a linear ($P < 0.01$) decrease in ADG, feed efficiency, and calculated dietary NE concentration, which contradicts the results from Parsons et al. (2001), who reported that feed efficiency and ADG were increased when roughage level was increased. However, Montgomery et al. (2003) used limit-fed diets, in which cattle were unable to compensate for a decrease in NE by effectively increasing DMI. When alfalfa hay was included at higher levels replacing DRC the NE content of the diet was decreased, although DMI remained constant.

Several previous research experiments evaluating feeding value of wet corn gluten feed suggested an optimum level of between 25 to 50% of the dietary DM. Hussein and Berger (1995) evaluated the effects of varied dietary levels of WCGF on feedlot performance, digestibility of nutrients, and carcass characteristics of growing and finishing Angus-crossbred beef heifers. For the growing phase, six treatments included either 25 or 50% WCGF (DM basis) offered at ad libitum intake, or 0, 25, 50, or 75% WCGF (DM basis) at restricted (80% of ad lib) levels of intake. After 127 d, heifers entered the finishing phase of the experiment and diets that were previously at restricted intake were offered ad libitum for the final 84-d finishing period. During the growing phase, the restricted feed intake (RFI) heifers fed WCGF diets gained less ($P = 0.008$) than heifers fed the high-corn diet. Moreover, the RFI heifers exhibited a linear decrease

(P = 0.003) in ADG with increasing level of WCGF in the diet. No differences (P >0.10) were detected for ad libitum fed diets during the growing phase; however, heifers that were initially at ad libitum intake had higher (P = 0.06) ADG and feed efficiency when offered the 25% WCGF vs. the 50% WCGF diet during the finishing phase. It was suggested that the superior performance associated with the 25% WCGF diet may have been partially a result of the greater percentage of corn in their diet compared to the 50% WCGF treatment. Furthermore, heifers that were on RFI during the growing phase demonstrated a positive response to WCGF in the finishing diet. Feeding WCGF tended to increase (P = 0.14) ADG by 9.3%, and a quadratic (P = 0.02) response was noted with the highest ADG exhibited at the 25% WCGF level. Berger and Willms (1992) had previously conducted a similar study in which corn-based diets containing 0, 25, or 50% WCGF (DM basis) were offered to beef heifers at restricted levels (90% of ad libitum) during the growing phase (84 d), and then at ad libitum consumption during finishing (86 d). Heifers fed the 25% WCGF diet gained as rapidly (1.34 vs. 1.30 kg/d) and as efficiently (0.206 vs. 0.199 gain:feed) as those fed no WCGF during both phases of growth; however, ADG and feed efficiency were compromised (P < 0.05) when heifers were fed the 50% WCGF diet. Results from both these studies would provide logic in feeding a diet that contains approximately 25% WCGF to finishing beef cattle.

Ham et al. (1995) conducted one growing and two finishing trials to determine the feeding value of WCGF in beef cattle diets. An 88-d growing trial using crossbred steer calves was performed to investigate the energy value of WCGF and the optimum level of inclusion in growing diets. Calves were allotted randomly within block to one of five treatments: (1) 44% dry-rolled corn (DRC), 5% molasses, 50% ground alfalfa hay; (2) 49% WCGF, 50% ground alfalfa hay; (3) 65% WCGF, 33% ground alfalfa hay; (4) 33% DRC, 33% corn silage, 33% ground alfalfa hay; and (5) 61% WCGF, 37% ground cornstalks. A mineral supplement was included to equal 100% dietary DM. Calves fed the 49% WCGF, 50% alfalfa hay diet gained 14% faster ($P < 0.10$) and 11% more efficiently ($P < 0.10$) than the calves fed the two controls diets. The authors suggested that because WCGF is a source of rapid and extensively digested fiber, WCGF may reduce negative associative effects associated with starch (grain), thereby increasing fiber digestion (Green et al., 1987). Additionally, increasing the level of WCGF from 49 to 65% increased ADG ($P < 0.10$) and feed efficiency ($P < 0.10$) without decreasing DMI ($P > 0.10$).

In the first of two finishing trials, Ham et al. (1995) evaluated effects of six different treatments consisting of a DRC (control), and diets replacing DRC with WCGF at levels of 35 or 70% (DM basis), or by substitution with 70% dry corn gluten feed (DCGF) with or without water to equal moisture content of the 70% WCGF diet. The sixth treatment was a diet combining 70% WCGF and 12% high-moisture (28% moisture) corn (HMC);(both on a DM basis). No significant differences were observed for ADG, DMI, or feed efficiency among cattle fed the control diet or the 35 or 70% WCGF + DRC diets. Cattle fed 70% DCGF or 70% DCGF + water were less efficient ($P < 0.10$) than cattle fed either the DRC control or 70% WCGF + HMC diets. This trend of reduced efficiency agreed with the findings of Firkins et al. (1985) and Trenkel (1987).

Ham et al. (1995) conducted their second finishing trial including five levels of WCGF at 17.5, 35.0, 52.5, 70.0, or 87.5% of dietary DM, which replaced 20, 40, 60, 80, or 100% of the control diet level of DRC and molasses. Although feed efficiency was not affected by WCGF inclusion, there was a quadratic response ($P < 0.05$) to ADG and DMI. Based on maximum ADG and DMI, 35% was the optimal level of WCGF in the diet. As mentioned previously, these results indicate a positive associative effect occurred for ADG and DMI when WCGF was included at 35% of diet DM.

Acute and Subacute Acidosis

Subacute acidosis is known to decrease DMI (Fulton et al., 1979) and feedlot cattle performance (Stock et al., 1990). Concentrate diets that are high in starch (grain) content are rapidly fermented in the rumen, and ruminal production of organic acids is markedly increased, which may be the culprit in acute and subacute acidosis in cattle (Owens et al., 1998). Because WCGF is a fibrous by-product of wet corn milling that may be similar in energy content to corn grain, it may be possible to include WCGF in the diet without a decrease in net energy, coupled with the benefits of decreasing the occurrence of subacute acidosis.

Krehbiel et al. (1995) conducted two experiments to determine whether wet corn gluten feed affected subacute acidosis in cattle. Experiment 1 was a 132-d finishing trial with five dietary treatments: (1) DRC control; (2) 35% WCGF fed d 1 through 132; (3) 86.5% WCGF fed on d 1 and decreased to 35% by d 19 with a corresponding increase in the proportion of DRC; (4) 86.5% WCGF fed d 1 through 132; or (5) 94.5% WCGF fed d 1 through 132. Additionally, all diets were fed with or without supplemental escape protein. Intake variation was recorded and analyzed using two different methods: (1) intake residuals within the day among all animals (AIV); or (2) intake residuals within the day among all animals within the treatment (DIV). Results from Exp. 1 revealed no WCGF x escape protein interaction ($P > 0.10$) so data were pooled across escape protein levels. Wet corn gluten feed and escape protein had no effect ($P > 0.10$) on AIV during the grain adaptation period. It was noted, however, that steers fed 86.5% WCGF on d 1, decreased to 35% WCGF by d 19, had greater ($P < 0.05$) DIV than steers receiving the other four treatments. Furthermore, on d 7 through 12, DIV was greater ($P < 0.05$) for steers fed DRC control than for steers fed 35, 86.5, and 94.5% WCGF On d 19 through 24, DIV was lower ($P < 0.05$) for steers fed WCGF than for steers fed DRC control diet. When the entire 24-d grain adaptation period was analyzed, DIV was greater ($P < 0.05$) for steers fed 86.5% WCGF on d 1, decreased to 35% WCGF by d 19 than for cattle fed 35, 86.5, and 94.5% WCGF, whereas DRC control steers were intermediate. Escape protein supplementation did not affect ($P > 0.10$) DIV On d 28, steers fed all WCGF diets were more efficient ($P < 0.05$) than steers fed DRC control. When observed throughout the entire 132-d finishing period, steers fed 86.5 and 94.5% WCGF had lower ($P < 0.05$) DMI and ADG than steers fed DRC control, 35% WCGF, or 86.5% WCGF decreased to 35% WCGF by d 19, although feed efficiency was not affected ($P > 0.10$) by treatment.

Experiment 2 conducted by Krehbiel et al. (1995) was an acidosis challenge experiment using three ruminally cannulated steers. Of each 14-d period, d 1 to 11 were used for dietary adaptation. On d 12, feed was withheld from each steer and 7.9 kg (DM) of 100% DRC, 50% DRC:50% WCGF, or 100% WCGF were dosed intraruminally to one of the three steers. Ruminal fluid was collected every 3 h during a 24-h period, ruminal pH was measured, and samples were frozen for later analyses. Steers dosed with 50% DRC:50% WCGF or 100% WCGF had a lower ruminal pH at 3 and 6 h after dosing than the 100% DRC treatment. The 50% DRC:50% WCGF and the 100% WCGF returned to initial pH values by 24 h. Conversely, ruminal pH in steers dosed with the 100% DRC did not return to initial values within 24 h. When pH was below 6.0, the overall decrease in ruminal pH during the 24-h sampling period was greater ($P < 0.05$) in steers dosed with the 100% DRC than in steers receiving any of the diets containing WCGF. It was suggested that although feeding cattle WCGF does not totally eliminate acidosis, starting cattle on diets containing WCGF may be an alternative to roughage when attempting to adapt cattle to high-concentrate diets. Furthermore, because WCGF is typically higher in net energy than roughage, the decrease in performance would be less substantial with WCGF compared with roughage in cattle fed receiving diets.

Ives et al. (2002) investigated the effects of virginiamycin and monensin plus tylosin on ruminal protein metabolism in steers fed corn-based finishing diets with or without wet corn gluten feed. In the current review, effects of wet corn gluten feed are of interest; therefore, results concerning the addition of the antibiotics will not be discussed. Ruminally cannulated steers were used in an extensive metabolism trial to evaluate effect of diets with or without WCGF. The two finishing diets were (DM basis): (1) 72% DRC, 12% soybean meal, and 10% chopped alfalfa hay (SBM); or (2) 63% DRC, 30% WCGF, and 5% chopped alfalfa hay. The primary difference in these diets was the source of CP, and the source and amount of fiber included. Overall, steers fed the WCGF diets consumed 8% more DM and OM ($P < 0.05$), along with 10% more CP, than steers fed the SBM diets. Ruminal pH was lower ($P < 0.01$) in steers receiving the SBM diet than in those fed WCGF, although total VFA concentration was greater for SBM steers than for those fed WCGF ($P < 0.05$). Furthermore, there was a three-fold greater ciliate protozoa population for steers fed WCGF It was suggested that the ability of protozoa to sequester starch and subsequently slow rate of fermentation in the rumen may have increased the ruminal pH observed in steers fed WCGF. Again, these results suggest that use of WCGF in high-concentrate diets could reduce the occurrence of ruminal acidosis, which is in agreement with the previous findings of Krehbiel et al. (1995).

In the Ives et al. (2002) study, steers fed WCGF had much greater ruminal α-amino acid concentrations at 2 h after feeding than steers fed SBM diets. When compared with SBM, ruminal NH_3 concentrations for WCGF were lower before feeding, higher 2 h after feeding, and then lower 8 to 10 h after feeding ($P < 0.001$). Firkins et al. (1984) reported similar results as only 27% of the original N in WCGF remained after 2 h compared with 52% for soybean meal. These data suggest that WCGF is higher in ruminally degraded protein than either DRC or SBM.

Herold et al. (2000) conducted a metabolism trial using ruminally cannulated calves (n = 3) and yearlings (n = 3) in a 3 x 3 Latin square design. Treatment diets consisting of: (1) a DRC control diet; (2) WCGF + DRC diet; or (3) WCGF + DRC + solvent-extracted germ meal diet were used to determine effects on ruminal acidosis. Dry matter intake, ruminal pH, and ruminal VFA concentrations were measured to estimate occurrence of acidosis. An acidosis challenge was administered by withholding feed 4 h after normal feeding time, and increasing available feed by 25% over the previous day to induce the potential for over consumption. Daily minimum pH was higher ($P < 0.10$) for the WCGF + DRC steers than for the DRC controls, and daily pH variance ($P < 0.05$) was decreased for both WCGF treatments. When area of pH below <5.6 was evaluated, steers fed DRC control diets tended ($P = 0.13$) to be greater than steers fed WCGF diets. Furthermore, total ruminal VFA ($P < 0.10$) as well as propionate ($P < 0.05$) concentration was greater for steers fed DRC control than for steers fed WCGF containing diets. In general, these data suggested that steers fed the WCGF diets were less likely to experience subacute acidosis than those fed DRC.

Sindt et al. (2002) evaluated three dietary treatments of 0, 30, or 60% WCGF, replacing portions of steam-flaked corn (SFC), molasses, urea, and SBM. A performance trial, in addition to microbiological analysis of ruminal fluid and feces to evaluate volatile fatty acid concentrations (VFA), pH, and acetate:propionate ratio, were conducted. Results from the performance trial indicated a quadratic response ($P = 0.02$) in ADG. Average daily gain was greatest for the 30% WCGF treatment (1.46 kg/d), intermediate for the 0% WCGF treatment (1.43 kg/d), and least for the 60% WCGF treatment (1.39 kg/d). A quadratic response ($P = 0.03$) also was noted for feed efficiency. Steers consuming the 30% WCGF diet were 1.8% more efficient than steers fed 0% WCGF; however, steers fed 60% WCGF were 6.7% less efficient than steers fed the 0% WCGF diet. Addition of WCGF also tended ($P = 0.07$) to linearly increase DMI.

Microbiological analysis of ruminal fluid indicated that increasing dietary WCGF resulted in a subsequent linear decrease ($P < 0.05$) in total ruminal VFA. Furthermore, acetate:propionate ratio and ruminal pH were linearly increased ($P < 0.05$) as level of dietary WCGF increased. Similar findings were reported for fecal analysis, as increased dietary levels of WCGF decreased ($P = 0.06$) total fecal VFA, and increased ($P < 0.05$) acetate:propionate ratio. Fecal pH increased ($P < 0.01$) with each rise of WCGF in the diet. Sindt et al. (2002) presented thorough discussion and suggested that moderate levels of WCGF used to replace SFC probably result in a positive associative effect as a result of the reduction of dietary starch supply and the lessened ruminal acid insult responsible for subacute acidosis.

Degraded and Undegraded Intake Protein

Wet corn gluten feed is considered to supply a significant amount of CP (22 to 24%) when included in beef cattle diets; however, a majority of the available protein is in the form of DIP (NRC, 1996). Beef cattle, particularly younger, newly weaned calves may require higher levels of escape protein (UIP), to be metabolized and used for tissue growth. It is uncertain whether the excess DIP provided by diets containing WCGF is metabolized and provided as escape protein. Furthermore, the high levels of DIP associated with WCGF diets may decrease or eliminate the need for a supplemental DIP source like urea. Therefore, future research is needed to determine the optimal level or combination of DIP and UIP supplemented in diets containing WCGF.

McCoy et al. (1998) conducted two receiving and two finishing trials to evaluate energy source and escape protein supplementation for calves. In Trial 1, steer calves were used in a 2 x 2 factorial arrangement of treatments in which factors were energy source (DRC or WCGF) and protein supplement (no escape protein supplementation or supplemental escape protein). Calves fed WCGF diets had decreased ADG ($P < 0.05$) and DMI ($P < 0.01$) compared to calves fed DRC diets. An improvement ($P < 0.10$) in feed efficiency was noted with escape protein (EP) supplementation, with a greater improvement (18%) seen in the calves fed WCGF diets. Average daily gain and DMI were not affected ($P > 0.15$) by EP supplementation. In Trial 2, arrangement of treatments were the same as in Trial 1, and calves fed WCGF gained similarly ($P > 0.15$), had decreased DMI ($P < 0.01$), and had greater feed efficiency ($P < 0.10$) than calves fed DRC diets. McCoy et al. (1998) implied that feeding WCGF in receiving diets might improve feed efficiency as long as requirements for metabolizable protein are met.

Wertz et al. (2001) conducted research to determine the affects of supplemented ruminally undegraded protein (UIP) and ruminally degraded protein (DIP) in crossbred heifers fed WCGF growing diets at base concentrate levels and various intake levels. In the current review, only data pertaining to protein source will be discussed. Half of a restricted intake treatment was supplemented UIP, whereas the other half was supplemented with DIP During the initial 42-d period, the UIP-supplemented heifers exhibited increased feed efficiency ($P = 0.05$) and tended ($P = 0.10$) to gain faster than DIP supplemented heifers; however, for the entire 84-d growing period ADG did not differ between protein sources. Likewise, feed efficiency for the entire 84-d period only tended ($P = 0.10$) to improve when UIP was included in limit-fed, WCGF growing diets.

Scott et al. (1997) determined the role of WCGF as a source of DIP for finishing steers. Three hundred twenty steers were blocked by BW and assigned randomly to one of eight treatments. Dietary treatments included (DM basis) SBM (5.0 or 10.0%), WCGF (10.4, 20.8, or 38.2%), corn steep liquor (10.4%), or alfalfa hay (7.5%). Soybean meal, WCGF, and corn steep liquor replaced equivalent proportions of DRC, and alfalfa hay replaced corncobs of a control DRC, corncob, and urea diet. Average daily gain was greater ($P < 0.10$) for steers fed the 7.5% alfalfa hay, 20.8% WCGF, 38.2% WCGF and the 10.4% corn steep liquor diets compared with the control steers. Gain:feed was greater ($P < 0.10$) in all treatments than for the control or the 10.4% WCGF treatments. It was suggested that the control and 10.4% WCGF diets might have limited amino acid and peptide availability, resulting in decreased performance. Inclusion of steep liquor resulted in superior ($P < 0.10$) feed efficiency compared with all other treatments. These results suggest that WCGF is a suitable replacement for SBM to supply DIP in diets fed to finishing steers.

Shain et al. (1998) investigated the effect of DIP level on finishing cattle performance and ruminal metabolism. Two finishing trials were conducted in consecutive years in which dietary treatments were supplementation with 0, 0.88, 1.34, or 1.96% urea (DM basis). Calculated CP levels of 9.7, 12.0, 13.5, or 15.0% were provided by the respective urea treatments. There were no significant differences in DMI, ADG, or feed efficiency among treatments containing urea (0.88, 1.34, or 1.96%). However, addition of urea at any of the three levels increased ADG ($P < 0.01$), and feed efficiency ($P < 0.01$) compared with the 0% urea treatment. Thus, urea supplementation proved advantageous, although levels above 0.88% (DM basis) did not enhance performance. Moreover, supplementation of urea in excess of animal requirements may be undesirable because of the subsequent nitrogen excretion into the environment. Gleghorn (2003) conducted two experiments to determine the effects of three different sources of CP fed at three different CP levels. Sources consisted of 100% urea, a 50:50 blend of urea and cottonseed meal, or 100% cottonseed meal. Each source was fed at levels of 11.5, 13, or 14.5% dietary CP (DM basis). Average daily gain was affected in quadratic manner ($P = 0.02$) by protein level, with 13% CP yielding the maximum gain. Protein source did not affect ADG for the overall feeding period; however, ADG was numerically greatest for cattle receiving supplemental CP from urea alone. Furthermore, feed efficiency was improved ($P = 0.03$) when CP was supplied solely by urea. Further research is needed to determine optimal level of urea supplementation in diets containing WCGF.

Conclusions from the Literature

In summary, the literature indicates that WCGF is an effective replacement for DRC in traditional high-concentrate diets. In several trials, performance by cattle fed WCGF diets was superior to that of cattle fed DRC. The NEg content of WCGF can equal, and in some reports it has exceeded, the NEg content of DRC, which might explain enhanced performance with WCGF containing diets. Increased availability of WCGF will provide producers an economical alternative to conventional high-starch diets fed to growing and finishing cattle. It is generally accepted that the optimal level of WCGF in finishing diets is between 25 to 35% of dietary DM.

Wet corn gluten feed contains significant levels of CP, particularly DIP The literature is not definitive concerning appropriate supplementation of DIP and UIP in WCGF diets. Nonetheless, WCGF is a significant source of DIP, and use of WCGF in finishing diets could decrease or eliminate the requirement for other DIP sources (e.g. urea). Further research is needed to determine the proper ratio and level of DIP and UIP in diets containing WCGF

Wet corn gluten feed is an ingredient with a high percentage of digestible fiber. When substantial levels of WCGF replace DRC in the diet, a decrease in the quantity of ruminal starch digested occurs, thereby decreasing ruminal organic acid load and the occurrence of acute and subacute acidosis. The lessened frequency of acute and subacute acidosis translates to greater and more consistent DMI patterns and greater ADG by growing and finishing cattle.

CHAPTER III

MATERIALS AND METHODS

Two hundred forty yearling crossbred, British x Continental, steers (average initial BW = 402.76 kg) were used in a randomized complete block design. Cattle were acquired from a single source in Walters, OK, and shipped approximately 337 km to the Texas Tech University Burnett Center located approximately 10 km east of New Deal, TX. The steers arrived May 28, 2003, at 1730 and were allowed access to water and approximately 4.5 kg/steer of a 65% concentrate receiving diet. On May 30, 2003, steers were assigned a uniquely numbered ear tag, vaccinated with bovine rhinotracheitis virus, bovine viral diarrhea, parainfluenza-3, and respiratory syncitial virus vaccine (Pyramid 4, Ft. Dodge Anim. Health, Overland Park, KS) and a seven-way clostridial (150 steers were given Vision 7 with SPUR [Intervet, Millsboro, DE], and the remaining cattle received Bar Vac 7; [Boehringer Ingelheim; Ridgefield, CT]). Processing also included deworming with Cydectin (Ft. Dodge Anim. Health). Steers were housed in soil-surfaced pens and gradually adapted to the final 91% concentrate (DM basis) diet via step-wise increases in concentrate level. A 72% concentrate diet was offered beginning June 2, 2003, an 81% concentrate diet was fed starting June 11, 2003, and the final 91% concentrate finishing diet was fed on June 18, 2003.

Pen was the experimental unit, with eight pens (one pen per block for each treatment) representing each treatment. Steers were allotted to weight blocks based on pre-trial (May 30, 2003) BW measurement arranged in descending order (heaviest to lightest). The 30 heaviest (BW) steers were in Block 1, the next 30 heaviest steers were in Block 2, and so on until all 240 steers were grouped into eight weight blocks. Random pen allotment was assigned within each weight block of 30 steers by randomly assigning a number (1, 2, or 3) that corresponded to a pen. After each of the 24 pens had 10 steers assigned, each pen within weight block was randomly assigned to one of the three treatments. Each steer also received a Revalor S (Intervet) implant in the right ear. On June 25, 2003 cattle were again weighed individually, and fed their assigned treatment diets (start of trial; d 0).

Treatment diets were steam-flaked corn-based. The 81% and the 91% concentrate diets both contained 25% (DM basis) Sweet Bran® brand (Cargill Corn Sweeteners; Blair, NE) wet corn gluten feed. Steers were fed three dietary treatments formulated to contain 14.1% CP, in which the ratio of supplemental N from urea and cottonseed meal was either 100:0 **(100)**, 67:33 **(67)**, or 33:67 **(33)** on a DM basis. Chopped alfalfa hay was included (9% DM basis) in all diets as the source of roughage (Table 3.1). Vitamins, minerals, Rumensin (30 g/ton DM basis), and Tylan (10 g/ton DM basis) were provided using a premix included at 2.5% of the dietary DM (Table 3.2).

Feed bunks were visually evaluated each morning (approximately 0700) to determine the quantity of feed to offer to each pen for the particular day. The bunk management philosophy was to allow for 0 to 0.23 kg of feed to remain at the time of evaluation, with the desired goal of maximum feed intake. The quantity of feed remaining in each bunk was estimated and recorded to determine feed intake for the previous day. A computer printout of the intake by each pen was available for the previous 3-d period. After determining the quantity of feed to be provided to each pen, a batch of each diet sufficient to supply the feed for all pens on a given treatment was mixed in the feed mill using a 45-cubic foot capacity Marion (Marion Mixers Inc., Marion, IA) paddle mixer and delivered via conveyor system to a Rotomix 84-8 (Rotomix; Dodge City, KS) delivery system. Following delivery of the given diet to the Rotomix 84-8, feed was distributed to the assigned treatment pens (± 0.45 kg) using load cells and an indicator contained on the Rotomix 84-8 unit. Weekly DM content was determined for each of the three diets, as well as Sweet Bran brand wet corn gluten feed, by drying grab samples in a 100° C forced-air oven for approximately 24 h. All weights for DM determinations were obtained on an Ohaus electronic balance (readability = ± 0.1 kg). At each 28-d interval feed bunks were cleaned and any unconsumed feed was weighed (Ohaus electronic scale; readability = ± 0.45 kg) to determine adjustments to DM deliveries to each pen. Weekly samples of feed were collected, and each 28-d weigh period, composited and ground through a 2-mm screen in a Wiley mill. Ground samples were subsequently analyzed for ash, CP, acid detergent fiber (Goering and Van Soest, 1970), Ca, and P content.

All individual BW measurements were obtained using a hydraulic chute (C & S; Garden City, KS) equipped with electronic load cells (Rice Lake Weighing Systems; Rice Lake, WI; readability = ± 0.45 kg). Interim weights were recorded using a pen scale (± 2.27 kg readability) on d 28, 56, 84, and 112 (Blocks 5 through 8) of the trial. Cattle in Blocks 1 through 4 were weighed individually on d 112 and shipped to slaughter as described in a subsequent section. On d 119 steers from Blocks 5 through 8 were weighed individually and shipped to slaughter. Both scales were calibrated with 454 kg of certified (Texas Department of Agriculture) weights immediately before use. One steer (33% treatment) was found dead of causes unrelated to treatment (chronic pneumonia) and was removed from the trial.

West Texas A&M University Beef Carcass Research Center personnel conducted carcass data evaluation. Routine carcass measurements were taken including hot carcass weight, longissimus muscle area, marbling score, percentage of kidney heart and pelvic fat, yield grade, quality grade, fat thickness measured between the 12^{th} and 13^{th} ribs, and incidence of liver abscess. Personnel were unable to collect data from 11 carcasses because of a plant error that prohibited direct measurement of hot carcass weight. Moreover, three steers were eliminated from the carcass data analyses because of excessive trim.

Performance data were analyzed using the Mixed procedure of SAS (SAS Inst. Inc., Cary, NC) for a randomized complete block design. The effects of treatment and block were included in the model for pen-based data, with linear and quadratic effects of urea level analyzed by use of orthogonal polynomials. Carcass data were recorded on an individual animal basis and analyzed for treatment, block, and block x treatment effects. Block x treatment was designated as the error term for evaluating treatment effects. Carcass quality grade and liver abscess score data were ranked using the Friedman's test (Conover, 1999) and the rank-transformed data were analyzed using the same model as performance data.

Table 3.1 Ingredient composition (% DM basis) of concentrate diets

	Proportion of urea in supplemental CP[a]		
Ingredient	33%	67%	100%
Steam-flaked corn	59.13	60.14	61.00
Alfalfa hay	8.96	8.95	8.96
Cottonseed meal	2.12	0.97	0.00
Urea	0.17	0.33	0.44
Fat (Yellow grease)	3.02	3.03	3.01
Sweet Bran[b]	24.13	24.13	24.13
Premix[c]	2.47	2.46	2.46

[a]33% = 33% urea:67% cottonseed meal; 67% = 67% urea:33% cottonseed meal; 100% = 100% urea:0% cottonseed meal (N basis).

[b]Sweet Bran® wet corn gluten feed; Cargill Corn Sweeteners, Blair NE.

[c]Composition of the premix is shown in Table 3.2.

Table 3.2 Composition of the premix used in experimental diets

Ingredient	%, DM basis
Ground corn	30.03003
Endox (antioxidant)[a]	0.50000
Limestone	42.10526
Dicalcium phosphate	1.03627
Potassium chloride	8.00000
Magnesium oxide	3.55872
Salt	12.00000
Cobalt carbonate	0.00174
Copper sulfate	0.15717
Iron sulfate	0.13333
EDDI	0.00252
Manganese oxide	0.26667
Selenium premix, 0.2% Se	0.10000
Zinc sulfate	0.84507
Vitamin A, 650,000 IU/g[b]	0.01218
Vitamin E, 500 IU/g[b]	0.12600
Rumensin, 176.4 mg/kg[b]	0.67499
Tylan, 88.2 mg/kg[b]	0.45005

[a]Kemin Industries, Des Moines, IA.

[b]Concentrations noted by ingredients are on a 90% DM basis.

CHAPTER IV

RESULTS AND DISCUSSION

Laboratory Analyses

Average ingredient composition of the experimental diets is presented in Table 3.1. Actual urea level was slightly greater than the formulated diet values; however, the desired proportion of urea:cottonseed meal level was not adversely affected by this difference. Crude protein content (Table 4.1) was somewhat lower than the formulated values. These lower CP levels in the diets were likely a function of less than anticipated levels of CP contained in corn used for this experiment. Percentage of Ca was less, and percentage of P was greater than the values expected from diet formulation. Average Ca values were 0.51, 0.51, and 0.50% (DM basis) for the 33, 67, and 100% treatments, respectively, whereas the formulated values were 0.59, 0.58, and 0.58% (DM basis), respectively. Results of P analysis averaged 0.55 (33%), 0.54 (67%), and 0.54% (100%) (DM basis), whereas formulated values were 0.49, 0.48, and 0.48% (DM basis) for the three respective treatments. Calculated Ca:P ratio for all three treatments was approximately 0.93:1. It has been suggested that in Ca:P ratios of 1.1:1 or less, metabolic problems can occur (Church, 1988); however, the NRC (1996) reported results from several previous studies (Wise et al., 1963; Ricketts et al., 1970; Alfaro et al., 1988) showing no differences in performance by cattle receiving Ca:P ratios ranging from 1:1 to 7:1. Based on exceptional animal performance in the current study, it would seem unlikely a Ca:P imbalance affected performance. Nonetheless, an effort should be made to achieve a Ca:P ratio of 1:1, particularly for diets containing WCGF. Sweet Bran® WCGF (unpublished data from Cargill Corn Sweeteners, Blair NE) has been estimated (SDK Laboratories, Hutchinson, KS) to contain only 0.05% Ca and 1.02% P (DM basis).

Cattle Performance

Final Body Weight. There was a quadratic effect (P = 0.03) for initial BW, and the very small differences among treatments were likely a result of random differences caused by blocking procedures. Initial BW was 405.2 (67%), 402.7 (100%), and 400.7 kg (33%) for the three treatments. There was a tendency (P = 0.14) for a linear effect of urea level on final BW. Final BW was greatest for the 67% treatment (633.2 kg), intermediate for the 100% treatment (629.8 kg), and least in steers fed the 33% diet (619.7 kg). To account for differences in gut fill at slaughter, adjusted final BW was calculated as hot carcass weight divided by the average dress of 61.95. Average final adjusted BW was greatest (634.3 kg) for the 67% steers and least (620.3 kg) for steers fed the 33% diet, with an intermediate value (630.4 kg) for steers fed the 100% diet.

Average Daily Gain. Data for ADG in the present study are presented in Table 4.4. From d 0 to 56, there was a quadratic (P = 0.06) effect for ADG in response to the proportion of urea in supplemental CP. Steers fed the 67% treatment gained 2.21 kg/d compared with 2.10 and 2.16 kg/d for steers fed the 33% and 100% diets, respectively. Average daily gain increased linearly (P = 0.10) by urea level from d 0 to 84 of the trial, as steers fed the 67 and 100% treatment diets had gains of 2.10 and 2.08 kg/d respectively, compared with 2.00 kg/d for the cattle fed the 33% diet. Similarly, from d 0 to 112, there was a linear effect of urea level on ADG (P = 0.09), with steers in the 33% treatment gaining 1.93 kg/d, and those fed the 67 and 100% diets gaining 2.00 and 2.04 kg/d, respectively. Carcass-adjusted ADG was greater (P = 0.08, linear effect) by steers in the 67 and 100% treatments compared with those in the 33% treatment (1.98 and 1.98 kg/d for 67 and 100% diets compared with 1.90 kg/d for the 33% treatment). Overall, and especially early in the feeding period, ADG was numerically greatest in the steers fed the diet with 67% urea:33% cottonseed meal. There have been conflicting results reported regarding ADG in cattle fed various sources and levels of DIP and UIP The results of the present study suggest that decreasing, and even eliminating a UIP source is not detrimental to ADG by yearling beef steers fed a steam-flaked corn-based diet containing 25% (DM basis) Sweet Bran® WCGF In contrast, Milton et al. (1997) reported that supplemental CP sources that contain a greater proportion of UIP are favorable compared with equivalent levels of CP supplied solely by urea (DIP). Shain et al. (1998) reported no differences in DMI, ADG, or feed efficiency among steers fed supplemental urea at 0.88, 1.34, or 1.96% (DM basis) in dry-rolled corn-based diets. It is important to note that the majority of the previous research concerning UIP and DIP supplementation involved diets that were based on dry-rolled corn. In the current study, steam-flaked corn was the primary energy source. Zinn et al. (2002) and Barajas and Zinn (1998) reported that steam-flaked corn results in a significant increase in the extent of ruminal starch digestion versus that of dry-rolled corn. Cooper et al. (2002) conducted a trial to determine the effect of corn processing on DIP requirement of finishing cattle, and reported that DIP requirement for maximum efficiency was 9.5% dietary DIP for steam-flaked corn-based diets, vs. 6.3% dietary DIP for dry-rolled corn-based diets. Barajas and Zinn (1998) examined the effects of dry-rolled vs. steam-flaked corn in finishing diets fed to yearling heifers, in which a blend of 10% CSM, 0.8% urea (DM basis) or 0.8% urea (DM basis) alone was supplemented. Inclusion of CSM tended to decrease ($P < 0.10$) feed efficiency compared with urea alone, as feed:gain ratio was higher for the heifers receiving 10% CSM and 0.8% urea diets. The authors concluded that increasing escape protein supply in a corn-based diet beyond that provided by urea supplementation alone does not improve cattle performance or the energy value of the diet. The increased microbial digestion of starch in the rumen, as likely occurred in the current study, may require greater levels of DIP (urea) supplementation to supply sufficient microbial protein for ruminal microorganisms (Galyean, 1996). Furthermore, UIP in the form of cottonseed meal seems to have limited effects on cattle performance when feeding a steam-flaked corn-based diet with 25% (DM basis) Sweet Bran® WCGF.

Dry Matter Intake. The DMI data are presented in Table 4.5. Increasing proportion of supplemental urea increased DMI, particularly in the early portion of the study. There was a linear ($P = 0.001$) increase in feed intake from d 0 to 28, as DMI increased with increasing proportion of urea supplied. Daily DM intakes of 9.33, 9.39, and 9.50 kg/steer were noted for the 33%, 67%, and 100% treatments, respectively. Dry matter intake also increased linearly ($P = 0.06$) from d 0 to 56, with maximum feed intake by steers fed 100% urea (10.18 kg/steer daily). Likewise, from d 0 to 84 average daily DMI increased linearly ($P = 0.08$) with increasing urea level. Average daily intake for the d 0 to 84 period was 10.19 (33%), 10.31 (67%), and 10.41 kg/steer (100%). Although not significant (P = 0.14), a trend was evident for the overall finishing period for numerically greater DMI with increasing level of supplemental urea. In a study conducted by Zinn and Shen (1998), DMI (P < 0.05) and ADG (P < 0.10) were greater by steers fed a steam-flaked corn-based diet of 0.8% urea diet versus a 4.5% soybean meal diet. In contrast, Gleghorn (2003) reported no relationship (P > 0.10) between DMI and supplemental protein source in diets containing either 100% urea, 50:50 ratio urea:cottonseed meal, or 100% cottonseed meal.

Feed Efficiency. There were effects of urea level on feed efficiency during several interim periods of the feeding trial (Table 4.4). For d 0 to 28 (P = 0.09), d 0 to 56 (P = 0.02), d 0 to 84 (P = 0.05), and for the entire feeding period (P = 0.09), there were quadratic responses for gain:feed ratio with increasing urea level. Cattle fed the 67% diet were most efficient during these periods, with gain:feed typically least for the 33% treatment and intermediate for the 100% treatment. Through the end of the trial, gain:feed was 0.189 for the 67% treatment, 0.187 for the 100% treatment, and 0.184 BW gain/kg DMI for the 33% treatment. Sindt et al. (1993) found that calves supplemented with a urea and 60:40 blend of blood meal:feather meal were more efficient (P < 0.05) than calves provided only urea from d 0 to 41. Results of the present study agree with those of Gleghorn (2003), who reported that feed efficiency in feedlot steers increased linearly with increasing percentage of CP supplied by urea. McCoy et al. (1998) reported an improvement (P < 0.10) in feed efficiency with escape protein supplementation vs. no escape protein supplementation. Likewise, research conducted by Wertz et al. (2001), in which supplemental UIP or DIP was fed to crossbred heifers, indicated that UIP-supplemented cattle exhibited improved feed efficiency ($P = 0.05$) early in the feeding period. It is important to note, however, that in both the current study and in previous research, larger effects on feed efficiency are realized in the early stages of the feeding period, and that typically differences in efficiency among treatments tends to diminish by the latter stages of the feeding period. This was evident in the present study, as neither linear or quadratic effects ($P \geq 0.13$) of urea level were noted for carcass-adjusted efficiency.

Carcass Characteristics. A summary of carcass characteristics is presented in Table 4.7. There tended to be a quadratic ($P = 0.14$) effect of urea level on hot carcass weight (HCW). Average HCW was 393.0 kg for the 67% treatment, whereas the 33% treatment averaged 384.3 kg, with an intermediate value of 390.5 kg for the 100% treatment. This difference in HCW would be expected considering the increased ADG and final BW discussed previously for the 67% treatment. Additionally, internal fat (kidney, pelvic, and heart fat) responded linearly ($P = 0.10$) to urea level, with higher values for the 67 and 100% treatments than for the 33% treatment. Although not significant, percentage of liver abscesses was greatest for the 33% treatment (12.25%); this was in contrast to an abscess rate of 8.26% for the 67% treatment and 7.50% for the 100% treatment. Barajas and Zinn (1998) reported ($P < 0.10$) a liver abscess rate of 25.00% in heifers fed a steam-flaked corn-based diet supplemented 10.0% CSM and 0.8% urea, but 5.00% in heifers receiving 0.8% urea without cottonseed meal. Reasons for an increased incidence of liver abscess associated with cottonseed meal supplementation in the Barajas and Zinn (1998) study are unclear. In the current study, perhaps increased levels of urea (67 and 100% diets) provided a limited buffering effect in the rumen. In a review, Owens et al. (1998) suggested that increasing ruminal input by feeds that yield bases (urea), may prevent a decrease in ruminal pH. A more favorable ruminal pH may decrease the incidence of acidosis, and subsequent damage to the ruminal wall, which can sequentially lead to liver abscess by entry of *F. necrophorum* into the hepatic portal vein. Yield grade, dressing percent, percentage of cattle grading USDA Choice, marbling score, backfat thickness, and longissimus muscle area did not differ ($P > 0.10$) among the three treatments.

Table 4.1 Chemical composition of the experimental diets[a]

Item	Proportion of urea in supplemental CP[b] 33%	67%	100%
Dry matter, %	76.13	75.73	75.97
Crude protein, %	13.45	13.42	13.54
ADF, %[c]	10.17	10.62	10.84
Ash, %	6.23	6.06	5.85
Ca, %	0.51	0.51	0.50
P, %	0.55	0.54	0.54

[a]All values except dry matter, % are expressed on a DM basis.

[b]33% = 33% urea:67% cottonseed meal; 67% = 67% urea:33% cottonseed meal; 100% = 100% urea:0% cottonseed meal (N basis).

[c]Acid detergent fiber, %.

Table 4.2 Effects of proportions of urea and cottonseed meal in the supplemental CP source on body weight and average daily gain by finishing beef steers fed diets containing 25% (DM basis) Sweet Bran®

	Proportion of urea in supplemental CP[a]				Contrast[b]	
Item	33%	67%	100%	SE	L	Q
Initial BW, kg	400.7	405.2	402.7	10.75	0.26	0.03
Final BW, kg	619.7	633.2	629.8	9.91	0.14	0.15
Adj. final BW, kg	620.3	634.3	630.4	9.83	0.15	0.14
ADG, kg/d						
d 0 to 28	2.07	2.29	2.19	0.085	0.32	0.12
d 0 to 56	2.10	2.21	2.16	0.040	0.24	0.06
d 0 to 84	2.00	2.10	2.08	0.030	0.10	0.14
d 0 to 112	1.93	2.00	2.03	0.042	0.09	0.67
d 0 to end[c]	1.90	1.98	1.97	0.031	0.13	0.26
Carcass-adjusted ADG, d 0 to end[d]	1.90	1.98	1.98	0.029	0.08	0.21

[a]33% = 33% urea:67% cottonseed meal; 67% = 67% urea:33% cottonseed meal; 100% = 100% urea:0% cottonseed meal (N basis).

[b]P value for linear (L) and quadratic (Q) effects of CP source (33% to 100%); n = 8 pens per treatment.

[c]Cattle were fed an average of 116 d.

[d]Adjusted final BW was calculated using the average dressing percent (61.95%) across all treatments.

Table 4.3 Effects of proportions of urea and cottonseed meal in the supplemental CP source on dry matter intake by finishing beef steers fed diets containing 25% (DM basis) Sweet Bran®

	Proportion of urea in supplemental CP[a]				Contrast[b]	
Item	33%	67%	100%	SE	L	Q
DM intake, kg/steer daily						
d 0 to 28	9.33	9.39	9.50	0.053	0.001	0.56
d 0 to 56	9.92	10.08	10.18	0.123	0.06	0.77
d 0 to 84	10.19	10.31	10.41	0.143	0.08	0.94
d 0 to 112	10.33	10.45	10.55	0.153	0.12	0.94
d 0 to end[c]	10.34	10.45	10.54	0.154	0.14	0.96

[a]33% = 33% urea:67% cottonseed meal; 67% = 67% urea:33% cottonseed meal; 100% = 100% urea:0% cottonseed meal (N basis).

[b]P value for linear (L) and quadratic (Q) effects of CP source (33% to 100%); n = 8 pens per treatment.

[c]Cattle were fed an average of 116 d.

Table 4.4 Effect of proportions of urea and cottonseed meal in the supplemental CP source on gain:feed ratio of finishing beef steers fed diets containing 25% (DM basis) Sweet Bran®

	Proportion of urea in supplemental CP[a]				Contrast[b]	
Item	33%	67%	100%	SE	L	Q
Gain:feed						
d 0 to 28	0.222	0.244	0.230	0.009	0.48	0.09
d 0 to 56	0.212	0.220	0.212	0.004	0.85	0.02
d 0 to 84	0.197	0.204	0.200	0.004	0.33	0.05
d 0 to 112	0.187	0.192	0.193	0.004	0.21	0.67
d 0 to end[c]	0.184	0.189	0.187	0.003	0.23	0.09
Carcass-adjusted gain:feed, d 0 to end[d]	0.184	0.190	0.188	0.003	0.27	0.13

[a]33% = 33% urea:67% cottonseed meal; 67% = 67% urea:33% cottonseed meal; 100% = 100% urea:0% cottonseed meal (N basis).

[b]P value for linear (L) and quadratic (Q) effects of CP source (33% to 100%); n = 8 pens per treatment.

[c]Cattle were fed an average of 116 d.

[d]Adjusted final BW was calculated using the average dressing percent (61.95%) across all treatments.

Table 4.5 Effect of proportions of urea and cottonseed meal in the supplemental CP source on carcass characteristics of finishing beef steers fed diets containing 25% (DM basis) Sweet Bran®

	Proportion of urea in supplemental CP[a]				Contrast[b]	
Item	33%	67%	100%	SE	L	Q
HCW[c]	384.3	393.0	390.5	6.10	0.15	0.14
Yield grade	2.89	2.93	2.87	0.09	0.83	0.64
Liver abscess, %	12.25	8.26	7.50	3.10	0.30	0.68
DP[d]	61.87	62.07	61.92	0.21	0.86	0.51
Choice, %[e]	43.9	34.9	44.0	5.89	0.99	0.23
Marbling score[f]	395.5	389.9	406.8	8.86	0.37	0.31
Backfat[g]	1.38	1.39	1.37	0.06	0.91	0.72
LMA[h]	92.03	93.59	93.79	1.77	0.32	0.65
KPH[i]	1.91	2.03	2.00	0.037	0.10	0.13

[a]33% = 33% urea:67% cottonseed meal; 67% = 67% urea:33% cottonseed meal; 100% = 100% urea:0% cottonseed meal (N basis).

[b]P value for linear (L) and quadratic (Q) effects of CP source (33% to 100%); n = 8 pens per treatment.

[c]Hot carcass weight.

[d]Dressing percent = (HCW/final live weight) x 100.

[e]Percentage of carcasses grading USDA Choice or better within a treatment

[f]Marbling score: 300 = Slight ^{00}; 400 = Small ^{00}; 500 = Modest ^{00}

[g]Backfat measured at the 12th rib (cm).

[h]Longissimus muscle area, cm^2.

[i]Percentage of kidney, pelvic, and heart fat.

CHAPTER V

CONCLUSIONS

Compared with a diet in which the ratio of supplemental CP supplied by urea and cottonseed meal was 33:67% (N basis), feeding a supplemental CP source containing at least 67% urea:33% cottonseed meal allowed for maximum feed efficiency and performance in finishing beef steers fed steam-flaked corn-based diets containing 25% Sweet Bran® WCGF (DM basis). Although performance was numerically greater when some cottonseed meal (UIP) was provided, eliminating a source of UIP from this type of diet did not significantly affect feed efficiency and overall performance.

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