Utilization of Whole Cottonseed and Hay in Beef Cow Diets[1]

G.M. Hill[2,3], M.H. Poore[4], D.J. Renney[3], A.J. Nichols[3], M.A. Pence[5], M.K. Dowd[6] and B.G. Mullinix, Jr.[7]
[3]Animal and Dairy Science Dept., Univ. of Georgia, Tifton Campus; [4]Dept. of Animal Sciences, North Carolina State Univ., Raleigh; [5]Vet. Diagnostic Laboratory, Tifton Campus, [6]Southern Regional Research Center, USDA-ARS, New Orleans, LA, [7]Experimental Statistics Dept., Tifton Campus

Introduction

Whole cottonseed (WCS) have become a very popular by-product feed for dairy cattle and for wintering beef cows in the Southern USA. The product is locally available to many producers across the region, and in most years WCS are competitively priced with other feedstuffs. Over time, ruminant nutritionists have recommended that WCS should be fed at about 0.5% of average body weight (BW), or about 2.3 to 3.2 kg WCS/cow daily (Rogers et al., 2002). The WCS provide both energy and protein (96% TDN and 23% CP, NRC, 1996; Feedstuffs, 2001). Research has indicated that WCS has a value similar to a 20% CP mixture of corn and soybean meal (Poore and Rogers, 1998). Beef cows can utilize WCS and hay very well, but younger growing cattle had diminished performance on WCS/hay diet compared with a corn/WCS meal diet (Hill et al., 2003; 2004), and performance decreased when WCS were fed at greater than 15% of diet DM in heifer diets (Poore, 1994). Feeding WCS at dietary levels higher than 0.5% of cow BW will supply excess fat in the diet, which could interfere with fiber digestion of the hay being fed. While ruminants have a fairly high tolerance for gossypol in WCS, excessive feeding of WCS could cause devastating effects on metabolism and health of cows. Nevertheless, some producers attempt to self-feed WCS, without actual knowledge of what intake levels may be, without regard to wasted money spent on WCS that was not consumed because it was trampled, refused because of being wet after rains, and not efficiently utilized because of over-consumption. After decades of feeding trials and producer usage of WCS as a supplement, few if any documented research trials have been conducted to determine how much WCS mature beef cows will consume.

Much of the hay grown across the region is inferior in quality, providing lower nutrient content and digestibility than the requirements of pregnant or spring calving beef cows. Supplementation with sources of energy and protein can increase nutrient content of diets and may enhance hay digestibility. Several companies have protein supplement products, usually with molasses-based carriers with added urea and natural protein sources, with varying levels of fat added for energy. Several liquid molasses-

[1]Research supported in part by a grant from Cotton, Inc., Cary, NC. Technical assistance of M. A. Tawzer, G. W. Stone and M. Keeler is gratefully acknowledged.
[2]Contact at: PO Box 748,Tifton, GA. 31794; 229-386-3215; E-mail: gmhill@uga.edu

based supplements are being fed in lick-wheel tanks for cows on pastures. More recently, weather-resistant hot-poured protein products (24% or 32% CP, 250 or 500 lb containers), some formulated with intake limiters, have increased in popularity, replacing stationary lick-wheel liquid product tanks on many farms. While feeding of liquid molasses supplements or poured protein products can be cost effective and enhance cow performance, WCS offers the advantage of additional energy with slower protein release in a compact, easy to feed natural package.

Therefore, during the last 3 yr, cow wintering experiments were designed to determine free-choice intake of WCS by mature beef cows during winter, and the effects on diet digestibility when WCS was fed at recommended levels and free-choice. In a 2007 study, the potential value of WCS as a supplement compared with a hot-poured molasses protein product fed with hay to beef cows was evaluated, with supplementation beginning just prior to initiation of calving, and continuing until the spring breeding season began. Hay and supplement intake, cow and calf gain, cow body fat changes, calf weaning weights, and cow pregnancy rates were determined.

Materials and Methods

Exp1. Cows Fed Hay with WCS at Three Levels. In the 2-year study, non-lactating, non-pregnant beef cows [42 cows/yr; no. cows/breed, for 2005, 2006, respectively; Angus (AN), n=12, 20; Polled Hereford (PH), n=6, 3; Brangus (BRA), n=16; 21; Braford (BRF) n=8, 7] were fed bermudagrass hay (Table 1) free-choice on six dormant bermudagrass pastures (0.89 ha each), and supplemented with three levels of WCS: 0.25% of BW (Low WCS), 0.5% of BW (Medium WCS), or free-choice (FC WCS) for 63 d beginning November 3, 2005, and for 70 d beginning October 5, 2006. Cows were fed hay free-choice in hay rings in each pasture. Cows were ranked by BW within breed type and stratified by cow age in six outcome groups. The six groups were then randomly assigned to three dietary treatments. Initial and final BW were averages of consecutive daily full weights, and cows were assigned visual body condition scores (BCS; scale 1 to 9; 1=emaciated; 9 =obese) on d 1 and the last day of each experiment. Rib fat and rump fat depths were measured by ultrasound on d 1 of each experiment, and within the final week of supplementation. A commercial mineral containing at least 8% P and salt (Beef 8®, W.B. Fleming Co., Tifton, GA) was available free-choice to all cows. Hay disappearance was closely monitored, WCS intake was measured on a daily basis. [All cows and steers were managed under procedures approved by the University of Georgia Animal Care and Use Committee Guidelines.]

In year two (2006), each cow was bled via jugular veinipuncture on d 42 and d 69; serum samples were analyzed for gossypol, and plasma was analyzed for lipids. A Bayer Advia 1200 Chemistry System (Siemens Medical Solutions Diagnostics, Tarrytown, NY) was used to analyze plasma samples for plasma urea nitrogen (PUN / Direct analysis), cholesterol (CHO; cholesterol / HDL), high-density lipoprotein (HDL), and triglycerides (TRIG). Cholesterol, TRIG, and D-HDL were measured directly. The low-density lipoprotein (LDL) was calculated using the formula: Total Cholesterol - (HDL [triglycerides/5]). The concentration of gossypol in serum (Table 6) was determined by forming a Schiff's base complex between gossypol and R-(-)-2-amino-1-propanol (CAS #35320-23-1). This complex was separated by reverse-phase HPLC, and then detected and quantified by UV absorption at 254 nm. The method has similarities to the procedure of Horn et al. (1999) for the measurement of gossypol in WCS and WCS meal. Hay and WCS consumption were closely monitored each year. Hay and WCS were periodically sampled and chemically analyzed (Table1) for DM and CP using AOAC (1990) procedures, and ADF and NDF were determined using methods outlined by Van Soest et al. (1991). The WCS was chemically analyzed for nutrients other than gossypol by Dairy One Laboratories, Ithaca, NY.

Exp. 2 Steer Dietary Intake and Digestibility of Hay with WCS. In 2006, large beef steers approximately 2 yr of age were selected to simulate effects of feeding mature beef cows varying levels of WCS with hay. Steers (n=28; initial BW 456.5 +/- 38.8 kg; breeding, AN X PH) were fed dietary treatments composed of: 1) Hay with no WCS; 2) Hay with WCS fed at 0.25% BW daily (Low WCS); 3) Hay with WCS fed at 0.5% BW daily (Med WCS); or 4) Hay with WCS fed free-choice (FC WCS). Steers were individually-fed Tifton 85 hay (Table 1) free-choice with treatment supplements for 17 d, and feed intake and feed refusals were recorded. Chromic oxide (10 g/steer daily last 10 days of trial) was fed as an indigestible marker in each experiment. Fecal samples (11/steer over last 5 days of each experiment) were collected, dried, ground through a 1 mm screen, and submitted for nutrient content and chromic oxide analyses to determine apparent digestion of organic matter (OM), CP and fiber digestibility. Nutrient and fecal analyses were conducted using the same procedures described for cow diets.

Exp. 3 Cows Fed hay with Poured Protein Product or WCS. Seventy eight pregnant mature (> 4 yr of age) beef cows (Brangus and Braford, Brahman derivatives) were assigned to six groups based on December BW, age, and breeding, before groups were randomly assigned to six paddocks of dormant pastures that were bermudagrass and bahiagrass mixtures. Cows were fed one of three treatments: 1) Hay only (H); 2) Hay plus commercial hot-poured protein tubs (HP; 24% CP, Sweetlix, Mankato, MN), or 3) Hay plus whole cottonseed (HWCS) at a rate of 0.5% of cow BW daily. Mixed bermudagrass hay was fed free-choice in hay rings in each pasture. Cows were weighed on two consecutive days to reduce ruminal fill effects on BW, BCS visually, and rib fat and rump fat were measured by ultrasound before assignment to treatment pastures on December 18 and 19, 2006, about 2 weeks prior to the initiation of calving season (January 1). Cows continued on the 3 treatments for 90 days, through the end of calving season (March 19, 2007). Ultrasonic fat (USF) depth over the 13th rib and rump and BCS (scale 1= emaciated; 9 = obese) were recorded on d 90. Cows were weighed on 2 consecutive days on d 89 and 90 (March 18 and 19, 2007), and cow and calf ADG were computed for the 90-d supplementation period. During the breeding season (79 d; March 26 to June 13, 2007), cows were assigned to different pastures with similar forage availability and species, depending on breed of bull to be used to service cows. Cows were exposed to either Angus or Brangus bulls that had passed BSE examinations. A commercial mineral containing 8% P and salt was available free-choice to all cows. Pregnancy rates were determined by rectal palpation of cows, verified by ultrasound 45 days after the breeding season ended. Calf weight change from birth to the end of supplementation period (d 90), from March 19 to end of breeding interval (d 190), from birth to end of breeding interval, and birth to weaning were determined. Cows and calves were reassigned to summer grazing treatments with regard to the original supplementation treatments, from June to weaning on September 13, 2007, when cow and calf BW at weaning and BCS of cows were determined. Hay disappearance, WCS intake, and supplement intake were carefully measured during the supplemental period (Table 8). Hay, poured protein tub product, and WCS were periodically sampled and chemically analyzed (Tables 5, 6 and 7) for DM and CP using AOAC (1990) procedures, and ADF and NDF were determined using methods outlined by Van Soest et al. (1991).

Statistical Analyses

The cow performance data (BW, ADG, BCS, and USF) for Exp. 1 were analyzed using Proc MIXED (SAS, 2002). The covariates listed in Table 3 were used to center 2-yr average cow performance data. Cow breeds included AN, PH, BRA, and BRF, and two Breed Types were designated: Breed Type 1= AN and PH; Breed Type 2= BRA and BRF. Cow Breed Type, cow age, initial BW, final BW were used to adjust BCS data. In Exp. 2, steer intake and digestion data were analyzed using Proc Mixed (2002), with hay DMI adjusted for steer BW as a covariable, and steer weight class and steer BW did not affect apparent digestion coefficients. For Exp. 3, cow performance data (BW, ADG, BCS, and USF) and reproductive data were analyzed using Proc MIXED (SAS, 2002). The BW and reproductive data were in one analysis, with means adjusted for these covariables when appropriate: cow initial BW; age of cow (AOD); cow breed type (Brangus, Braford, ¾ Angus1/4Brahman); calf birthweight; calf BW at d 90; calf age at d 90; calf breed type (Brangus, Angus X Braford, Angus crossbred calves). Calf performance data were analyzed using Proc Mixed (2002), with means adjusted for covariables: cow initial BW, age of cow (AOD), calf birthweight, calf breed type, calf BW at d 90, calf age at d 90 when appropriate.

Results and Discussion

Cows in Exp. 1 were assigned to treatments in autumn each year, and fed hay with three levels of WCS. Cows were in good body condition and health. Hay and WCS analyses for multiple samples of each feed source are shown in Table 1. The WCS had typical CP and fat content for Southeastern cotton, but TDN values were below many published values. These analyses were conducted by Dairy One Laboratories, Ithaca, NY, and the formulas they use to compute TDN consistently result in lower TDN values for WCS than other laboratories. Bermudagrass hay contained approximately 11 % CP (Table 1), typical, but higher than the average bermudagrass hay produced in the region. Hay was harvested using conventional disc mowers and round balers, and stored outside, following the practice of many Southeastern beef producers. The hay alone would meet the protein requirements of dry beef cows (NRC, 1996), and supplemental WCS insured no deficiencies.

The 2-yr intake of WCS and hay (Exp. 1; Table 2) was similar in each year for the FC WCS treatment. The level of WCS was held constant at 0.25% or 0.5% of cow initial BW during the experiment for Low WCS and Med WCs treatments. Hay disappearance was greatest ($P < 0.01$) for cows on the Med WCS treatment, intermediate for FC WCS, but lowest for the Low WCS. This data suggests that feeding WCS at the recommended level of 0.05% BW actually stimulated hay intake. The WCS intake (Table 2) indicated that cows consumed substantially higher daily amounts of WCS on the FC treatment than on Low or Med WCS treatments, as expected, since WCS intake was limited on the Low and Med WCS treatments. The FC cows consumed cottonseed at 4.06 kg DM/d (8.93 lb DM/cow; 9.81 lb/d WCS as-fed). Based on fat content of the WCS, this resulted in FC WCS cows consuming 0.73 kg fat/d (1.61 lb fat/cow daily), which was a huge amount of fat to be metabolized by ruminal microbial populations. Interestingly, cows on the FC WCS treatment had the highest total DMI, with both Med WCS and FC WCS having similar, but higher ($P < 0.01$) total DMI than cows on the Low WCS treatment. This occurred from the stimulation of hay intake by feeding WCS on the Med WCS and FC WCS treatments, added to the substantial consumption of WCS by FC WCS cows. No noticeable diarrhea or adverse effects of high WCS consumption on FC WCS were noted in either year of the study. However, intake patterns were different for each pen of cows on the FC WCS treatment each year (Figure 1). The figure shows constant intake of WCS for Low and Med WCS treatments, which were averaged for the two pens of cows each year. However, cows on FC began the study at the Med WCS level, and were challenged with increased WCS offered every two days until intake leveled off after 6 wk each year. By d 28 in each year, WCS intake was above 5 kg DM/cow daily (> 11 lb/cow, as-fed) for each replicate of the FC WCS treatment (Figure 1). In each year, one replicate of cows had decreased WCS intake by d 42, but the other replicate continued to consume high levels of WCS. In 2005, one FC WCS replicate dropped to about 4.75 kg/d after d 28, and was below the WCS intake of Med WCS cows by d 56; however, the other FC WCS replicate continued to consume WCS at levels greater than 5.0 kg/d from d 21 to d 63. In 2006, similar intake patterns occurred compared with 2005, but both FC WCS replicates dropped under 5.0 kg WCS daily after d 28. Then, as in 2005, one replicate remained at about 4.5 kg WCS daily through d 56, before dropping to 3.0 and 3.5 kg/d at d 63 and d 70. The other replicate dropped from 5 kg/d at d 28 to about 4.5 kg/d at d 35 and d 42, then declined further to about 2.0 kg/d by d 49 and d 56. These FC WCS cows had increased WCS intake during the final two weeks, increasing to about 3.4 kg/d at d 63 and d 70. Therefore, some cows on the FC WCS treatment displayed aversion to WCS after experiencing very high (> 5.0 kg/cow daily) WCS intake. During these intervals, hay consumption was not observed to increase in any measurable amount for the replicates experiencing declining WCS intake. It is interesting to note that in 2005, one replicate continued to consume > 5.0 kg WCS/day until the experiment ended, but the other replicate never regained previous intake. In 2006, one replicate remained around 4.5 kg/d after d 28, but one replicate dropped dramatically, and neither replicate rebounded to d 56 levels. Therefore, results suggest that free-choice feeding of WCS to beef cows could lead to erratic intake in herds of cows, and that there is apparently a difference in tolerance and metabolism of cows fed higher levels of fat, fiber, and protein.

Cow performance was affected by WCS supplementation of hay-based diets (Exp. 1; Tables 3 and 4). In Table 3, means of various factors used as covariates to adjust performance and body fat least squares means are presented. Cows used in the study were older (*P* < 0.05) and heavier (*P* < 0.01) in 2006 than in 2005, but USF rib fat, USF rump fat, and BCS were similar for cows each year. Cow ADG, change in rib fat depth, and change in rump fat depth were affected by year of the study. More 3- and 4-year-old cows that had lower BCS were used in 2005 than 2006, resulting in higher overall BW gain of cows in 2005. With the increased WCS consumption by FC WCS cows, and their higher (*P* < 0.01) total DMI (Table 2), these cows had higher ADG than Low WCS or Med WCS cows. The change in US rib fat depth was greatest (*P* < 0.05) for FC WCS, intermediate for Med WCS, and lowest for Low WCS, with actual losses of rib fat recorded for cows on Low WCS. Rump fat depth change was higher (*P* < 0. 01) for Med WCS and FC WCS cows than for Low WCS cows. A Breed Type X cow age interaction (*P* < 0.10) affected cow ADG and cow rib fat depth change (Table 4). For cows less than three years of age, Breed Type 2 cows had higher ADG than Breed Type 1 cows (*P* < 0.05), but breed type did not affect cow ADG of cows that were greater than four years of age. Additionally, Breed Type 2 cows that were less than three years of age had higher ADG than cows that were greater than 4 yr of age, indicating more compensatory gain in the younger Breed Type 2 cows. The Breed Type X Cow age interaction for change in rib fat (Table 4) shows similar rib fat change increases for cows less than 3 yr of age of each breed type, but a marked depression of rib fat depth for Breed Type 2 cows that were greater than four years of age. While ultrasound data was based upon a specific cross section site for fat depth over the rib and rump, BCS values reflected visual appearance of the cow along back, rib, rump and brisket. The BCS data (Table 5) indicated that cows had similar initial BCS on each treatment in each year. In 2005, final BCS scores were higher (*P* < 0.05) for Med WCS and FC WCS cows than for Low WCS cows, and Low WCS cows had lower final BCS than initial BCS, indicating a loss of condition on this treatment. In 2006, final BCS was greater than initial BCS for all treatments, however greater (*P* < 0.01), final BCS were recorded for Med WCS and FC WCS.

The effects of level of WCS fed on serum gossypol and plasma lipids are shown in Table 6. In 2006, cows were bled on d 42 and d 69, with FC WCS having WCS intake greater than 4 kg/d on d 42, and approximately 3.8 kg/d by d 70 (Figure 1). At d 42, total serum gossypol was 46% higher for FC WCS than Low WCS, and 17% higher for FC WCS than Med WCS (Table 6). Similarly, the (-) isomer of serum gossypol in FC WCS cows was more than twice the concentration observed in Low WCS. At d 69, total serum gossypol was 33% higher for Med and FC WCS than Low WCS, and the (-) isomer concentrations followed a similar pattern. All serum gossypol values were probably mediated by absorption, liver activity, digestion processes and dilution by the hay diet. Nevertheless, at d 42 when FC WCS intake was highest, total serum gossypol and the (-) isomer concentrations were substantially elevated. Although WCS intake was approximately 3.8 kg/d for each replicate of the FC WCS treatment by d 69 (Figure 1), serum total and (-) isomer gossypol concentrations were similar for Med and FC WCS (Table 6). Although not as severe in 2006 compared with 2005, WCS intake declined on the FC WCS treatment. The apparent aversion for WCS observed for one replicate in 2005 might have been caused by toxic effects of gossypol in the very high consumption until d 42 (Figure 1). However, cows in both years did not show usual clinical signs of toxicity outlined by Rogers et al. (2002), and total DMI was similar for Med and FC WCS treatments (Table 2). Virtually all of the gossypol in WCS is in the free form, so free and total gossypol values for WCS should be almost identical (Pons et al., 1953). The free form is toxic, but the bound form is not because it usually is not released in the rumen. Furthermore, the (-) isomer of gossypol apparently has the most biological activity, and it is responsible for the toxic effects of gossypol (Rogers et al., 2002).

With the substantially higher levels of CP and crude fat consumed by FC WCS cows, one would expect higher PUN and blood lipid concentrations. The PUN was similar at d 42 and d 69 for Med and FC WCS treatments, each of which was higher than Low WCS (Table 6). The hay CP and the slower release of ammonia from the WCS probably increased PUN on the Low WCS treatment to levels about 20% lower than Med and FC WCS. The increased WCS consumption did not raise PUN values for FC WCS substantially above Med WCS. Plasma CHO was higher for Med and FC WCS than Low WCS on both sampling dates (Table 6). Although triglyceride and HDL were not affected by treatment, LDL increased for Med and FC WCS treatments compared with Low WCS. While increased CHO resulting from fat supplementation has been associated with increased reproductive performance, a trend was observed for lower plasma CHO on FC WCS compared with Med WCS. The slower release of fatty acids from WCS, better balance of fiber, protein and fat, and the increased dietary fat on Med WCS might have increased plasma CHO. Long et al. (2007) reported increased serum CHO when beef heifers were supplemented with a rumen protected fat source fed with corn gluten feed on pasture before breeding.

In Exp.2, heavy beef steers similar in BW to many beef cows were used to determine total tract digestibility of WCS fed in diets similar to those in the cow experiments. Hay CP and quality was somewhat higher than feeds used in the cow experiments, and hay averaged above 14% CP, well above CP requirements for the steers (Tables 1). [Hay DMI was reduced with increasing WCS intake across treatments (Table 7), with the lowest hay DMI on the FC treatment. In Table 7, WCS intake was highest ($P < 0.01$) for FC WCS intermediate for Med WCS, and lowest for Low WCS, resulting from feeding the three levels of WCS.] Total diet DMI was highest for FC ($P < 0.01$), intermediate for Low and Med WCS, and lowest for H. Total DMI and WCS DMI, especially on FC WCS was affected by the short duration of the steer digestion experiment. If Figure 1 from the cow study is examined, it indicates that cows fed WCS FC had increasing WCS intake for at least 6 weeks before declining. Therefore, it is remarkable that steers on FC WCS consumed the levels indicated in Table 7 by the end of the 17-day experiment, and intake was increasing at the end of the experiment. Most steers on FC WCS were consuming about the same amount of WCS, with little evidence of aversion. The OM, ADF and NDF apparent digestibility coefficients were greater ($P < 0.01$; Table 7) for Hay Only and Low WCS than for FC, and intermediate for Med WCS. Interestingly, CP digestibility increased ($P < 0.01$) for Med WCS, but declined for FC WCS to the same level as H. The ether extract percentage of diets increased dramatically from 2.1 to 7.6 % across the four treatments, which probably decreased OM and fiber digestibility. Steers on the FC diet had reduced DMI and severely reduced OM and fiber digestibility. In a similar study using 2-yr old steers and the same dietary treatments as in this study, Hill et al. (2007) reported depressed OM and fiber digestion for the FC WCS treatment, although FC WCS steers did not attain the level of WCS consumption reported in the present study. These results further underscore the contention that cows will consume more WCS than many producers believe they will consume, resulting in economic losses and decreased efficiency in digestibility of hay and WCS. Although cows on FC WCS had numerically higher total DMI (Table 2), higher ADG (Table 4; $P < 0.05$), both OM and fiber (ADF and NDF) digestion were diminished when steers were fed the FC WCS diet.

The question was asked, how much WCS will mature beef cows consume? This question was answered in Exp.1, with cows averaging 4.06 kg/d of WCS DM—far more than many producers expect cows to consume. The question became more critical with significantly increased actual costs of WCS in 2007-2008. Whole cottonseed bought in bulk at the gins in autumn at harvest ranged from $65/t to $95/t, in South Georgia in 2005-2006 with increasing prices during winter and spring. In October, 2007, WCS were priced at $150/t to $180/ton at the same gins, and on January 9, 2008, the FOB price at Memphis, TN, was quoted at $252/t. Few could afford to self-feed the product at these prices without knowledge of expected DMI. At $252/t (higher with transportation costs), the WCS cost alone would be $1.24 / d, if cows consumed 9.81 lb WCS/day, as indicated in Exp.1. Additionally, total dietary digestibility of hay would be reduced. Feeding WCS at the recommended levels of 0.05% cow BW is supported by this research.

In Exp. 3, cows were assigned to supplement treatments about 2 wk before calves began to arrive in January, 2007. Hay, protein tub supplement, and WCS consumption are shown in Table 8. Hay consumption or disappearance was consistently lower for cows on HWCS, than for cows on H and HP treatments, which had similar hay disappearance. Hay composition is shown in Table 9, and average CP was 13.1% on a DM basis—much higher than the typical bermudagrass hay fed to cows in the Southeastern United States. Hay had average TDN of 55, and fiber components were in acceptable ranges. The higher CP and TDN of this hay probably allowed cows on H to gain and reproduce at higher than expected levels. On the HWCS treatment WCS was fed at a constant daily amount (0.5% BW; Table 8) The protein supplement intake (Table 8) presented some issues, because one replicate pen of cows on the HP treatment consistently consumed more of the product than the other replicate pen of cows. In Table 6, the nutrient composition of several drilled samples of the protein supplement averaged 30.66% CP on a DM basis, which was very near the 24% CP as-fed stated on the label. However, only 1% fat was found in poured protein supplement samples (Table 9), when the label stated that the blocks contained 5% fat. Furthermore, the manufacturer predicted on the label that 454 kg (1,000 lb) cows should consume 0.45 to 0.91 kg (1 to 2 lb) of product daily. Cows in Exp. 3 weighed in excess of 544 kg (1,200 lb), and the average treatment consumption of the product was 0.27 kg/cow daily (0.59 lb/cow daily) for 90 days. Perhaps, the higher CP of the hay being fed (Table 9) met CP needs of the cows, and tended to reduce intake of the protein supplement. The research data indicated that the replicate pen of cows that had lower protein supplement intake also had lower hay intake (Table 8). The chemical analyses of the WCS are shown in Table 9, and the composition was typical for CP, averaging 24% CP, but the 69% TDN value was lower than many literature values (Feedstuffs, 2001: 96% TDN; NRC, 1996: 90 % TDN). The lower TDN values are consistent with other cottonseed analyses conducted by Dairy One, Ithaca, NY, and it is apparently related to formulas they use to calculate TDN. The fat content of the WCS in our study tended to be lower than expected, averaging 15.7% ether extract (Crude Fat), but other samples from other experiments usually have fat in the 19 to 22% range.

Cows were calving throughout the 90-d supplementation period, which might have influenced both cow BW and BCS. At the end of the 90-d supplementation period, cows on HWCS had greater ($P < 0.05$) average BW than cows on H (Table 10). The HWCS cows had higher ($P < 0.05$) ADG than HP cows, and HP cows had higher ($P < 0.05$) ADG than H cows. In Table 2, cows on the HWCS treatment had higher visual BCS on d 90 than cows on HP or H, which supports the increased ADG noted for HWCS cows during the supplementation period (Table 10). However, ultrasound fat depths over the rib and rump of the cows were similar at d 90 for all treatments. This may be explained by the fact that these measurements were taken at single sites on the cow body, whereas the BCS scores take into account the overall condition of the cow all along the back, tailhead, brisket, and over the ribs. Cows on H actually had BW and ADG losses (Table 10) during the supplementation period, while those on HP had slightly positive ADG. These results indicate that feeding WCS to late pregnancy beef cows increased ADG and BW during the pre-breeding and calving interval, and these gains were higher than those of cows fed either a protein supplement or hay alone. The cows on HWCS had higher performance because of the protein and energy supplied by WCS, even though hay fed on all treatments was of relatively good quality (Table 9; Avg. 13.1% CP on DM basis, 55% TDN).

In Exp. 3, by d 268 at weaning, cows had returned to approximately the same BW they had initially in December (Table 10). But ADG losses were greater ($P < 0.13$) for H and HP than HWCS from d 1 to d 268 at weaning. During the spring (from March to June), a record harsh drought occurred that resulted in insufficient pasture forages to support cows nursing calves, so hay and pelleted corn gluten feed supplementation was implemented for all cows for approximately 30 days, during the latter part of the breeding season. Relief finally arrived with the first spring rains associated with Tropical Storm Barry supplying 10 to 15 cm (4 to 5 inches) of rain during the first week of June, 2007. Cow pregnancy rates were apparently unaffected by treatments ($P < 0.14$; Table 10), or by the harsh drought conditions, because pregnancy rates were above 88% for each treatment. The average estimated number of days pregnant was similar for all treatments, indicating that supplementation and the harsh drought conditions that lasted through most of the breeding interval did not affect conception dates of cows. According to these estimated fetal ages at time of examination, the average conception dates for H, HP, and HWCS, respectively, were: April 26, May 2, and April 29.

The BCS for cows and rib and rump USF depth are shown for various key dates and time intervals (Exp. 3; Table 10). Initial BCS and USF measurements were nearly equal for each treatment. As mentioned, on d 90 cows on the HWCS treatment had higher (P < 0.02) visual BCS than cows on HP or H. However, on d 90, USF were unaffected by dietary treatments. Cows on all treatments had lower rib and rump fat on d 90 than on d1, with negative changes in these fat depots. This is a normal phenomenon observed during calving and early lactation of cows on average beef cattle diets. While the overall change in rib fat depth from d 1 to d 90 was negative by similar amounts for all treatments, cows were regaining body condition as the season progressed.

Calf performance (Table 11) indicated that calf birthweights and average calf ages tended to be lower for calves on H than calves on HP and HWCS. These effects were functions of the breeding program, and assignment of cows to treatments without knowledge of estimated fetal calf age on d1 of the experiment. Feeding cows hay only on the H treatment might have lead to lower calf birthweights on this treatment. On d 90, calf weights tended to be higher (P <0.16) for calves on HWCS than calves on HP. Calf ADG were similar for all treatments (P < 0.73), but numerically higher for the lower birthweight, younger calves on H than HP or HWCS. Calf ADG for the various time periods displayed the same trends, with highest ADG for H, intermediate for HP and lowest ADG for calves on HWCS. These results might have been influenced by milk production of the cows randomly assigned to the three treatments. Calf weaning weights, 205-d adjusted weaning weights, and calf ADG from birth to weaning (Table 11) were unaffected by dietary treatment. In the weeks prior to weaning, pasture forages were probably as important as waning milk production of cows in sustaining calf gains.

Research with beef cows and large steers verified earlier recommendations relative to feeding WCS as a supplement with hay. The recommended level of WCS feeding at 0.5% of BW supplied adequate energy and CP for non-pregnant cows, and as a pre-breeding supplement for winter-calving cows. In our experiment, cows had higher ADG and BCS when fed 0.05% BW WCS compared with a poured protein product. Apparent digestion of hay and WCS diets by large steers was unaffected by WCS feeding at 0.05% BW, but free-choice feeding of WCS at higher levels depressed OM and fiber digestion. Feeding WCS free-choice to cows was not cost effective before the recent upturn in WCS prices.

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Table 1. Chemical composition of hay and WCS fed to cows and digestion trial steers Exp.1.

Item	DM	CP	ADF	NDF	Fat	TDN, %
	-------------------------% DM Basis			------------------------------		
Cottonseed						
Cows-2005	92.5	22.4	39.2	54.7	18.0	72
Cows-2006	91.8	24.6	42.6	57.6	17.7	71
Steers-2006	91.1	25.9	49.9	67.4	15.0	74
Hay						
Cows-2005	91.5	11.3	55.7	78.4	1.4	53
Cows-2006	92.4	10.5	40.0	76.2		54
Steers-2006	91.1	13.7	41.0	74.5	1.9	

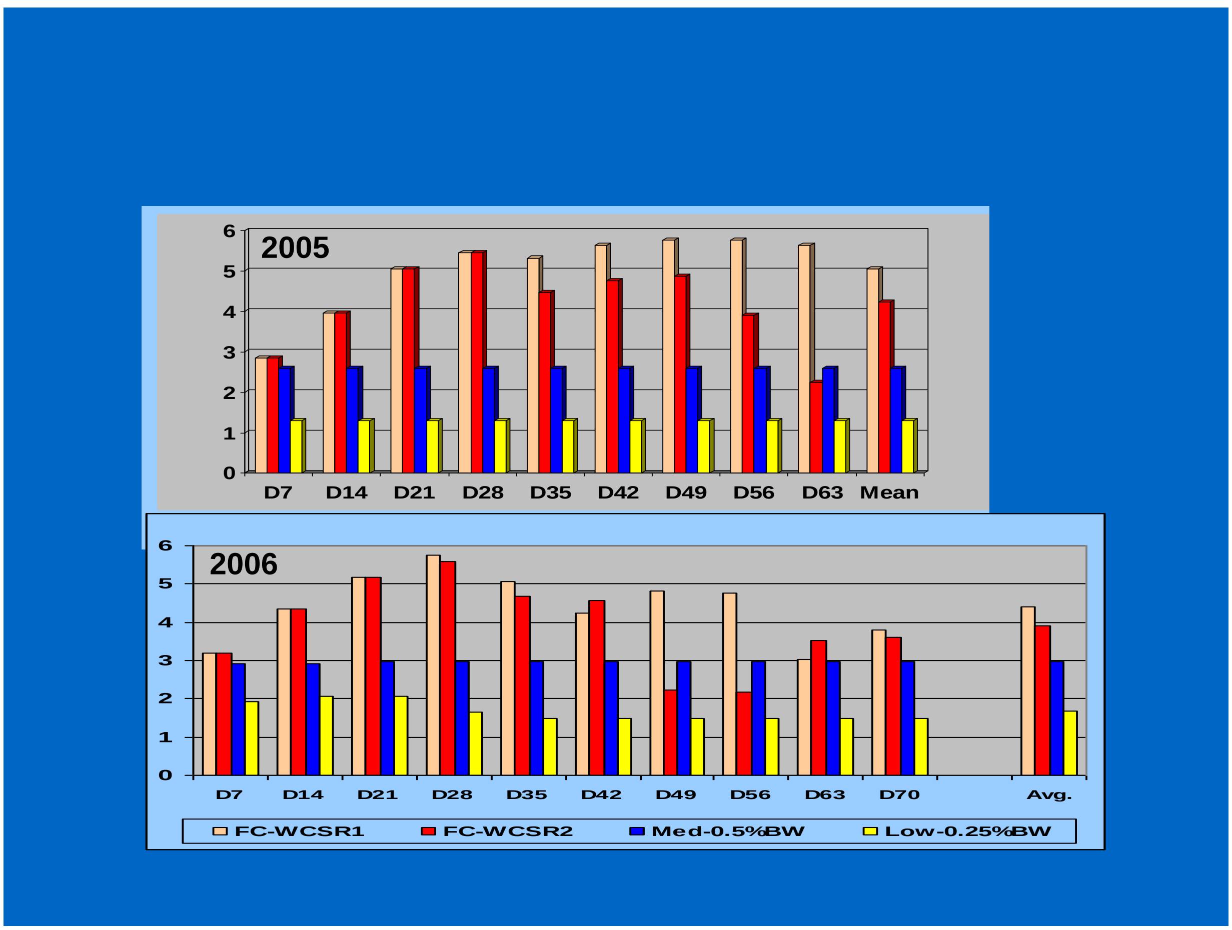

Figure 1. Weekly intake by cows of WCS in Exp.1 fed at 0.25% BW, 0.50% BW or free-choice [2-yr as-fed basis, kg/d; showing intake for each replicate for cows on free-choice (FC) WCS: FC-WCS R1 =Rep 1; FC-WCS R2 =Rep 2].

Table 2. Two-year average (2005, 2006) hay disappearance and cottonseed consumption by cows in Exp. 1.

Item	Low WCS 0.25%BW	Med WCS 0.50% BW	High WCS Free-Choice	SE
No. cows/Trt each yr	14	14	14	
Disappearance of hay, kg/d	9.48[b]	11.50[a]	10.36[ab]	0.38
WCS DMI, kg/d	1.41[b]	2.41[b]	4.06[a] (8.95 lb)	0.24
WCS fat intake, kg	0.25	0.43	0.73	
Total DMI, kg/d	10.90[b]	13.91[a]	14.42[a]	0.42

Abbreviations: WCS = Whole cottonseed; Trt=Treatment.
[ab]Means with different superscript letters differ (*P* < 0.01).

Table 3. Covariates used in Exp. 1. to center 2-yr average cow performance when WCS was fed at three levels with hay.

Covariate	2005 Mean +/-SD	2006 Mean +/-SD	*t* value
Initial BW, kg	517.4 +/- 99.2	578.9 +/- 78.4	3.15*
Cow age, yr	3.67 +/- 1.87	6.33 +/- 2.88	5.02**
Initial BCS (1-9)	4.5 +/- 1.11	4.5 +/- 0.81	0.00
Initial US ribfat, cm	0.60 +/- 0.43	0.78 +/- 0.27	2.30
Initial US rump fat, cm	0.55 +/- 0.61	0.51 +/- 0.22	0.40

*(*P* < 0.05)
**(*P* < 0.01)

Table 4. Cow ADG and ultrasound fat (USF) changes with breed type x cow age interactions (Exp. 1).

Item	2005	2006	SE	Low WCS	Med WCS	High F C WCS	SE
ADG, kg	0.54[x]	0.43[y]	0.05	0.36[r]	0.45[r]	0.59[q]	0.04
Change USF rib fat, cm	-0.06[b]	0.15[a]	0.04	-0.08[r]	0.07[q,s]	0.14[q]	0.05
Change USF rump fat, cm	0.01[b]	0.32[a]	0.05	0.04[b]	0.21[a]	0.25[a]	0.04

Breed Type X Cow Age Interactions

	Cow Age	Breed Type 1 AN & PH	Breed Type 2 BRF & BRA	SE
ADG, kg	< 3 yr	0.44[r]	0.63[q]	
	> 4 yr	0.41	0.44[r]	0.07
Change Rib USF, cm	< 3 yr	0.01	0.07	
	>4 yr	0.12[r]	-0.02[q]	0.05

[a b] Means bearing different superscript letters differ (*P* < 0.01).
[q r s] Means bearing different superscript letters differ (*P* < 0.05).
[x y] Means bearing different superscript letters differ (*P* < 0.10).

Table 5. Cow BCS for cows supplemented with cottonseed in 2005 and 2006 (Exp. 1).

Item	Year	Low WCS 0.25%BW	Med WCS 0.50% BW	High WCS Free-Choice	SE
Init BCS[k]	2005	4.61	4.46	4.44	0.14
Fin BCS[l]		4.31[y]	4.92[x]	4.91[x]	0.12
Init BCS[m]	2006	4.58	4.51	4.36	0.26
Fin BCS[n]		4.70[b]	5.26[a]	5.31[a]	0.11

[a b] Means bearing different superscript letters differ (*P* < 0.01).
[x y] Means bearing different superscript letters differ (*P* < 0.05).
[k]Initial BCS covariate adj: breed type (*P* < 0.06), cow age (*P*<0.07), initial BW (*P* < 0.01)
[l]Final BCS covariate adj: initial BW (*P* < 0.05), Initial BCS (P<0.01)
[m]Initial BCS covariate adj: breed type X Trt (*P* < 0.20), initial BW (P < 0.01)
[n]Final BCS covariate adj: initial BCS (*P*<0.01), initial BW (*P* < 0.01).

Table 6. Serum gossypol and plasma lipids in cows fed cottonseed in 2006 (Exp. 1).

Item[a]	Low WCS 0.25%BW	Med WCS 0.50% BW	High WCS Free-Choice
No. cows	14	14	14
Serum gossypol	------------------------ ug/ml -----------------------------		
Day 42 Total (% + isomer)	0.88 (55.2)	1.34 (54.6)	1.62 (54.94)
+ isomer	0.44	0.74	0.92
- isomer	0.35	0.62	0.75
Day 69 Total (% + isomer)	0.70 (54.5)	1.05 (54.1)	1.05 (51.2)
+ isomer	0.39	0.56	0.54
- isomer	0.33	0.48	0.51
Plasma components	-----------------------mg/dl--------------------------------		
Day 42			
Plasma urea nitrogen	12.93	15.21	15.63
Cholesterol	183.57	226.00	207.96
Triglyceride	24.07	23.64	23.24
High-density lipoprotein	83.21	96.57	93.19
Low-density lipoprotein	94.42	124.21	110.07
Cholesterol / HDL	2.21	2.35	2.26
Day 69			
Plasma urea nitrogen	13.14	15.00	15.43
Cholesterol	193.57	231.07	218.64
Triglyceride	34.93	30.79	32.57
High-density lipoprotein	89.29	94.93	94.43
Low-density lipoprotein	97.43	130.14	117.64
Cholesterol / HDL	2.16	2.44	2.33

[a]Table contains raw means without statistical analyses.

Table 7. Steer DMI of dietary components and apparent digestibility by steers (Exp. 2).

Item	Hay	Low WCS, 0.25% BW	Med WCS, 0.50% BW	High WCS, Free-choice	SE	*P* <
	----------------------------DMI, kg -------------------------------					
Hay	5.92[a]	5.25[b]	5.23[b]	4.50[c]	0.12	0.01
WCS[d]	-----	1.24[c]	2.30[b]	3.68[a]	0.10	0.01
Total	6.18[c]	6.49[c]	7.53[b]	8.18[a]	0.12	0.01
	--------------Total diet apparent digestibility, % --------------					
OM, %	75.0[a]	75.0[a]	73.7[ab]	62.7[b]	1.15	0.01
CP, %	80.3[b]	81.6[ab]	82.5[a]	80.2[b]	0.60	0.01
ADF, %	68.6[a]	68.4[a]	67.1[ab]	53.3[b]	1.58	0.01
NDF, %	75.3[a]	75.0[a]	73.3[ab]	61.1[b]	1.34	0.01

[abc] Means bearing different superscript letters differ ($P < 0.01$).

[d]Steers on all treatments were fed corn (0.23 kg/d DM)as a carrier for chromic oxide, and the values for total DMI include this corn.

Table 8. Hay disappearance and supplement intake for cows fed hay, hay with Sweetlix® protein tubs[a] , or hay with 0.5% BW whole cottonseed for 90 d in winter (Exp. 3).

		Trt 1 (H)	Trt 2 (HP)		Trt 3 (HWCS)		HayStatistics
Item	Rep	Hay Only	Hay	Prot Tub[a]	Hay	WCS	*P* <
		------------------	kg/d, as-fed basis	--------------------			
Day 43	1	24.6	21.5	0.36	18.9	2.96	
	2	20.6	23.4	0.53	19.6	2.96	
Mean		**22.6**	**22.4**	**0.45**	**19.2**	2.96	**0.115**
Day 90	1	19.1	16.3	0.19	15.1	2.96	
	2	16.3	18.4	0.35	15.8	2.96	
Mean		**17.7**	**17.3**	**0.27**	**15.5**	2.96	**0.175**

Abbreviations: Trt=Treatment; (H) = Hay only, (HP) = Hay with Protein Tub; (HWCS) = Hay with WCS fed at 0.5% BW; WCS = whole cottonseed, BW = body weight.
[a]Based on 453.5 kg cow, cattle should consume 0.45 to 0.90 kg of block/head daily (Sweetlix® recommendation).

Table 9. Chemical analyses of round bale hay, whole cottonseed, and poured protein product in tubs fed to cows Dec.19, 2006—March19, 2007, 90 days (Exp. 3).

Item	DM	CP	ADF	NDF	NFC	EE fat	TDN, %
	-------------------------------	%, DM basis	---------------------				
Hay[a]	92.1	13.1	38.9	71.4	11.1	3.0	55.2
WCS[b]	91.8	24.1	46.0	60.2	----	15.7	69.6
Protein tubs[cd]	82.8	30.7	5.9	11.3		1.0	

Abbreviations: WCS = whole cottonseed.
[a]Mean of analyses conducted on hay samples from 12 round bales. Each sample analyzed was the composite of three core samples (one taken from end and 2 at 45 degree angles from sides of each hay bale) on four sampling dates during the 90-d feeding experiment, using an electric drill and a 24 inch Penn State hay probe.
[b]Nutrient composition of WCS fed to beef cows. During the 90-d feeding experiment, individual WCS samples (n=10) were analyzed by Dairy One, Ithaca, NY.
[c]Commercial poured protein product: Sweetlix®, PO Box 8500, Mankato, MN 56002. Manufacturer guaranteed analysis: CP (min) 24.0%, (not more than 18% equivalent CP from non-protein nitrogen); crude fat (Min) 5.0%; crude fiber (Min) 6.0%; Ca (Min) 0.50%; Ca (Max) 1.0%; P (Min) 0.08%; salt (Min) 2.5%; salt (Max) 3.00%; Mg (Min) 3.0%; K (Min) 2.0%; Se (Min) 3.4 ppm; Vitamin A (Min) 15,000 IU/lb; Vitamin D-3 3750 IU/lb; Vitamin E 3.75 IU/lb.
[d]Based on 453.5 cow, cattle should consume 0.45 to 0.90 kg of block/cow daily (Sweetlix® label recommendation.

Table 10. Cow performance when fed hay, hay with protein tubs, or hay with 0.5% BW whole cottonseed for 90 d in winter (Exp. 3).

Item	Trt 1 (H) Hay	Trt 2 (HP) Hay + Protein Tub	Trt 3 (HWCS) Hay + 0.5% BW WCS	SE	Trt *P* <
No. Cows (13/rep.)	**26**	**26**	**26**		
Initial BW, (12/19/06), kg	**577.4**	**574.7**	**577.9**		
Initial Cow BCS	4.92	4.84	4.89	0.10	0.87
D 1 US Rib fat, cm	0.53	0.56	0.54	0.06	0.96
D 1 US Rump fat, cm	0.32	0.34	0.32	0.06	0.96
D 90 BW (3/19/07), kg[d]	**567.3[b]**	**579.6[ab]**	**603.8[a]**	5.76	**0.09**
D 90 cow ADG, kg[d]/d	**-0.10[c]**	**0.04[b]**	**0.30[a]**	0.05	**0.01**
D 90 Cow BCS[e]	**5.11[b]**	**4.99[b]**	**5.45[a]**	0.12	**0.02**
Change BCS d 1-d 90[e]	**0.19**	**0.14**	**0.55**	0.13	0.38
D 90 US Rib fat, cm[e]	0.37	0.35	0.39	0.05	0.81
D 1-d 90 change rib fat, cm[e]	-0.16	-0.21	-0.15	0.04	0.57
D 90 US Rump fat, cm[e]	0.32	0.25	0.30	0.05	0.60
D 1-d 90 Change rump fat, cm[e]	-0.00	-0.09	-0.02	0.04	0.37
D 268 BW at wean, kg	**559.0**	**558.7**	**572.0**	**5.40**	0.13
D 1 to D 268 ADG, kg/d	-0.06	-0.06	-0.01	0.04	0.13
Cow pregnancy rate, %	89.2	96.3	87.6	5.65	0.14
No. days pregnant (7/19/07)[f]	82.1	75.7	78.8	5.13	0.71

Abbreviations: Trt=Treatment, (H) = Hay only, (HP) = Hay with Protein Tub; (HWCS) = Hay with WCS fed at 0.5% BW; WCS = whole cottonseed, BW = body weight; D = day; US = ultrasonic measurement of fat depth; BCS = body condition score (visual, scale 1-9); ADG = average daily gain. Experiment dates: D 1 = Dec. 19, 2006; D 90 = Mar. 19, 2007; D 268 = September 13, 2007, weaning date for calves.

[a,b,c] Means separated if overall Trt means differ; if followed by different letters, differ (P < 0.05).

[d]Means adjusted for covariables when appropriate: cow initial BW; age of cow (AOD); cow breed type (Brangus, Braford, ¾ Angus1/4Brahman); calf birthweight; calf BW at d 90; calf age at d 90; calf breed type. Mean cow initial BW for all cows = 576.67 +/- 60.31 kg.

[e]Means adjusted for covariables: Cow initial BW; age of cow (AOD).

[f]Cow breeding season: March 26 to June 13, 2007 (79 days).

Table 11. Calf performance when cows were fed hay, hay with protein tubs, or hay with 0.5% BW whole cottonseed for 90 d in winter (Exp. 3).

Item	Trt 1 (H) Hay	Trt 2 (HP) Hay + Protein Tub	Trt 3 (HWCS) Hay + 0.5% BW WCS	SE	Trt P <
No Calves (2 Reps)	25	24	26		
Calf Birthweight, kg	37.8	40.8	39.9	1.10	0.15
Calf age on D 90, d	43.7	46.6	51.0		
D 90 Calf BW, kg[c]	88.2	86.2	90.9	2.82	0.16
D 1-d 90 Calf ADG, kg[c]/d	1.21	1.16	1.16	0.05	0.73
D 190 Calf BW, kg	194.2[a]	189.8[ab]	184.4[b]	3.31	0.11
D 190 Calf ADG, kg/d	1.05[a]	1.02[ab]	0.99[b]	0.05	0.14
D 90-d 190, ADG, kg/d	1.06[a]	1.02[ab]	0.96[b]	0.04	0.11
Calf Weaning wt., kg[d]	255.7	260.7	255.2	3.42	0.65
Calf 205-d Adj Wt, kg[e]	237.3	240.6	235.9	4.37	0.73
ADG Birth to Wean, kg/d	0.97	0.98	0.96	0.03	0.65
ADG d90 to weaning, kg/d	0.93	0.97	0.93	0.10	0.65

Abbreviations: Trt=Treatment; (H) = Hay only, (HP) = Hay with Protein Tub; (HWCS) = Hay with WCS fed at 0.5% BW;WCS = whole cottonseed, BW = body weight; D = day; ADG = average daily gain.

[a,b] Means separation: means followed by different letters, differ ($P < 0.05$); refer to Trt probability for treatment differences..

[c]Means adjusted for covariables: cow initial BW; age of cow (AOD); calf birthweight; calf BW at d 90; calf age at d 90.

[d]Calf weaning wt. adj. for covariables: Calf breed type, calf BW at d 90, calf age. Calf weaning weights (lb) were different ($P< 0.01$) for cow breed types: Brangus, Braford, ¾ AN1/4Brahman, respectively, 587[a], 582[a], 532[b], SE 7.51.

[e]Calf 205-d Adj.wean wt adj. for covariables: Calf breed type, calf BW at d 90, calf age; calf 205-d adj. weights were different ($P< 0.01$) for cow breed types: Brangus, Braford, ¾ AN1/4Brahman, respectively, 542[a], 538[a], 494[b], SE 8.39.

SESSION NOTES