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Summary and Implications

Because treatment with calcium oxide (CaO) will increase the digestibility of corn stover, CaO-treated corn stover may be a cost-effective alternative to a portion of corn grain in beef feedlot diets. Single-pass harvested corn stover was ensiled either untreated or treated with 5% CaO on a dry matter (DM) basis. Ground baled stover, untreated stover silage, or CaO-treated stover silage were fed at 20% of the diet DM with modified distillers grains with solubles and corn grain at 40 and 35% of the DM and fed either during the growing phase or both the growing and finishing phases in comparison to a control diet containing baled stover, modified distillers grains with solubles, and corn grain at 5, 20, and 70% of the diet DM. The DM digestibilities of diets fed to sheep that contained the baled stover, untreated stover silage, and CaO-treated stover silage diets were 75.9, 75.5, and 83.2%, respectively. In the beef feeding trial, 210 steers (30 per treatment; mean weight 648 lb) were either fed the control diet to finish or fed the baled stover, untreated stover silage, CaO-treated stover silage diets for either the growing phase to 1,000 lb or to finish. Daily gains of steers fed the control treatment or the CaO-treated stover silage diet were greater than steers fed the CaO-treated stover silage diet during the growing phase or untreated stover silage diet to finish which were greater than steers fed the baled stover silage diets to finish or the untreated stover silage during the growing season. Steers fed the CaO-treated stover silage diet to finish had a lower feed-to-gain ratio than any other treatment. Steers fed the control treatment had a higher marbling score than those fed diets containing any of the corn stover treatments. Calcium oxide treated stover is a cost-effective replacement for a portion of the corn in feedlot diets.

Introduction

Increasing competition for corn grain for processing and export may constrain the availability and increase the price of corn grain as a feedstuff for livestock and poultry diets. While distillers grains with solubles may partially replace corn grain in the diets of feedlot cattle, the amounts of distillers grains with solubles in feedlot diets may be limited by its high sulfur, oil, and protein concentrations. Therefore, a feedstuff providing a competitively priced alternative to corn as a source of available carbohydrate in feedlot diets is needed. Residues of corn grain production, including the stalk, leaf, husk, and cob, comprise the stover which contains approximately half of the dry weight of a standing corn plant and have been used in small amounts of feedlot diets to provide fiber to maintain rumen health. However, although generally being low-priced, they are not used as an energy source in ruminant diets because of their low digestibility.

Alkali treatments to enhance the nutritional value of low quality grass roughages for cattle have been recognized for decades. Treatment of straws and stovers with anhydrous ammonia, sodium hydroxide, calcium hydroxide or other strong bases degrade a portion of the linkages between lignin and hemicellulose in the fiber in these grass roughages, thereby increasing the availability of the cell wall carbohydrates for digestion by the rumen microbes. However, the cost and management of such treatments have limited their wide-spread implementation. But recent changes in grain prices and the potential for continued competition for corn grain in the future may make chemically treated corn crop residues a cost-effective replacement for a portion of the corn in feedlot diets.

Therefore, an experiment was conducted to evaluate the effect of calcium oxide treatment of corn crop residues on the digestibility of dry matter and fiber in feedlot diets containing a high concentration of modified distillers grains with solubles and to assess replacing a portion of the corn in the diets with calcium oxide-treated corn crop residues during the growing and finishing phases on body weight gains, feed efficiency, carcass characteristics and net economic returns from feedlot cattle.

Materials and Methods

In October, 2009, approximately 75.6 tons of corn stover (59.7% DM) were harvested with single-pass equipment from a farm near Ankeny and transported to the Iowa State University Beef Nutrition Farm near Ames. One half of the harvested corn crop residues were immediately packed into a silo bag to produce the untreated stover silage. The remaining stover was left on a concrete surface until it could be packed into a silo bag. During that time, 2.38 inches of rain fell, thereby, increasing the moisture concentration of the stover considerably. At the time of packing the second bag, calcium oxide (CaO) was added as reactive lime powder by hand to the stover at 5% on a dry matter (DM) basis to produce the CaO-treated stover silage. Silages were stored for 95 days prior to the initiation of a feeding experiment. In addition to the stover silages, large round bales of corn stover that were harvested in the fall of 2009 near Cedar Rapids were transported to the Iowa State University Beef Nutrition Farm, stored outdoors, and tub-ground through a 4-inch screen as needed during the experiment.

Corn stovers were used to produce 4 diets fed to growing-finishing cattle (Table 1). The Control diet contained 70% corn grain, 20% modified distillers grains with solubles, 5% of a vitamin-mineral supplement, and 5% baled corn stover on a DM basis. The Baled, Untreated silage, and CaO-treated silage diets contained 35% corn, 40% modified distillers grains with solubles, 5% of a vitamin-mineral supplement, and 20% of the baled stover, untreated stover silage, or CaO-treated stover silage, respectively, on a DM basis.

In January, 2010, 210 Angus and Angus-cross steers (mean BW, 648 lb) were weighed on two consecutive days, blocked on the mean of the two weights, and randomly allotted to one of 35 pens in a feedlot. Pens were blocked by position in the feedlot and randomly allotted to one of seven treatments: 1) A control treatment fed the Control diet during both the growing and finishing phases; 2) A Baled stover-Control treatment fed the Baled stover diet during the growing phase to an average pen weight of 1,000 lb and the Control diet during the finishing phase; 3) An Untreated stover silage-Control treatment fed the Untreated stover silage diet during the growing phase and the Control diet during the finishing phase; 4) A CaO-treated stover silage-Control treatment fed the CaO-treated silage during the growing phase and the Control diet during the finishing phase; 5) A Baled stover treatment fed the Baled stover diet during both the growing and finishing phases; 6) An Untreated stover silage treatment fed the Untreated stover silage diet during both the growing and finishing phases; and 7) A CaO-treated stover silage treatment fed the CaO-treated stover silage diet during both the growing and finishing phases.

Diets were mixed in a mixer wagon and delivered to all pens assigned to that treatment once daily. Diet ingredients were sampled monthly and the diets were sampled weekly. Uneaten feed was weighed and sampled as needed. Feed ingredients, diets and uneaten feed were analyzed for dry matter, neutral detergent fiber (NDF), and acid detergent fiber (ADF). In addition, all stovers were analyzed for acid detergent lignin. All steers were implanted with estradiol benzoate at the initiation of feeding and with estradiol benzoate and trenbolone acetate after 112 days of feeding. Steers were weighed monthly without shrinking. Steers fed the Control treatment were harvested when all steers reached a backfat thickness of 0.4 inches, as visually estimated. Steers from other treatments were harvested when the average body weights of steers in each treatment equaled the harvest weight of steers in the Control treatment. During the feeding trial, 2 steers from separate pens fed the Untreated stover silage-Control treatment were removed from the trial for reasons seemingly unrelated to the experiment.

Concurrent with the feeding trial, the digestibilities of the dry matter, neutral detergent fiber, and acid detergent fiber of the diets containing the Baled stover, Untreated stover silage, and CaO-treated stover diets were determined in a digestion trial with three wether lambs (mean BW, 86.7 lb) in metabolism stalls. The design of the digestion trial was a 3 x 3 Latin square with 10-day adjustment and 5-day collection phases. During the adjustment phase, diets were fed at the amount needed to supply metabolizable energy at 1.5 times the maintenance requirements of the lambs receiving the Baled stover diet. During the collection phase, diets were offered at an amount equal to that of the adaption phase minus the daily orts collected during the adaption phase. During the collection phase, feces were weighed and a 10% subsample was collected, dried at 65^{o}C for 48 hours, and ground through a 1-mm screen for analysis of NDF and ADF.

All data were analyzed by the Mixed procedure of SAS (SAS Institute Inc., Cary, NC). Data from the feeding trial were analyzed with a model with fixed effects of block and treatment and a random effect of the block by treatment interaction with pen as the experimental unit. Differences between means with significant treatment effects were determined using the PDIFF procedure of SAS. Data from the digestion trial were analyzed as a Latin square design with a model with fixed effects of period, sheep, and treatment and a random effect of the sheep by period interaction. Differences between means with significant treatment effects were determined using the PDIFF procedure of SAS. All data are reported as LSmeans.

An economic analysis was conducted to evaluate the sensitivity of cost of production and returns per head to variation in corn price. Feed prices assumed included corn price at $4, $5 or $6 per bushel. Modified distillers grains were priced at 65% of the corn price, on a dry matter basis. Other feed prices assumed were baled stover at $55/t, bagged non-treated stover at $59/t, bagged treated stover at $51/t and supplement at $400/t. Stover was priced at a similar dry matter value with additional costs of $8/ton added for bagging, and $7.50 per ton added for CaO treatment (bagging and treatment costs applied on an as-fed basis). Non-feed costs were estimated at $.45/hd/day. Individual carcass values were determined using a base price for a USDA Choice, yield grade 3 of $148 per cwt. Discounts assumed were $8.50/cwt for USDA Select, $20/cwt for no-rolls and $12.50/cwt for yield grade 4. Premiums used were $3.50/cwt for Certified Angus Beef, $15/cwt for USDA Prime, $2/cwt for yield grade 2 and $4/cwt for yield grade 1. The purchased price used in the economic analysis was $105/cwt.

Results and Discussion

Diets containing the CaO-treated stover silage had a higher ($P<0.05$) dry matter digestibility than diets containing either baled stover or untreated stover silage diet (Table 2). Similarly, the digestibilities of NDF and ADF in the CaO-treated stover silage diet tended to be greater than the baled stover and untreated stover diets.

Although, it was intended to finish all cattle at body weights comparable to steers fed the control diet during both the growing and finishing phases, finished body weights of steers fed the control treatment were greater ($P<0.05$) than steers fed the baled stover diets either in the growing phase alone or both in the growing and finishing phases or the untreated stover silage during the growing phase (Table 3). However, there were no differences in finished body weights of steers fed the CaO-treated stover silage diet either during the growing or both the growing and finishing phases, steers fed the untreated stover silage diet during both the growing and finishing phases, and steers fed the control treatment.

As expected, average daily gains of steers fed the baled stover or untreated stover silage diets either during the growing phase or total feeding period were lower ($P<0.05$) than steers fed the control treatment. Likely because of the high digestibility of the CaO-treated stover silage diet, average daily gains of steers fed the CaO-treated stover silage diet during the growing phase and total feeding period did not differ from steers fed the control diet. However, apparently because of reduced bodyweight gains during adjustment from the CaO-treated stover silage diet fed during the growing phase to the control diet during the finishing phase, total average daily gains of steers fed the CaO-treated stover silage diet only during the growing phase were lower ($P<0.05$) than steers fed either the control treatment or the CaO-stover silage treatment.

Feed DMI steers fed the control treatment were greater ($P<0.05$) than those fed any of the stover diets during the growing phase. During the growing phase, dry matter intakes of steers fed the baled stover diet were greater ($P<0.05$) than the CaO-treated stover silage diet which were greater ($P<0.05$) than steers fed the untreated stover silage diet. Total dry matter intakes during the feeding period did not differ among steers fed the control, baled stover, and untreated stover silage diets throughout the feeding period, but was greater ($P<0.05$) than steers fed the CaO-treated stover silage diets throughout the feeding period or fed baled stover, untreated stover silage, or CaO-treated stover silage only during the growing phase.

The feed-to-gain ratios of steers fed the control treatment during the growing phase were lower ($P<0.05$) than steers fed the baled stover diet. Similarly, the feed-to-gain ratios of steers fed the CaO-treated stover diet during the growing phase were lower ($P<0.05$) than steers fed the baled stover or untreated stover silage diets. However, feed efficiency did not differ between steers fed the control treatment or fed the CaO-treated stover silage diet during the growing phase. The overall feed-to-gain ratios of steers fed the CaO-treated stover silage diet during both the growing and finishing phases were lower ($P<0.05$) than all other treatments. The overall feed efficiency of steers fed untreated stover silage or CaO-treated stover silage diets did not differ from those fed the control treatment. Steers fed the control treatment had lower ($P<0.05$) feed-to-gain ratios than steers fed the baled stover diet either during the growing phase alone or both during the growing and finishing phases or fed the untreated stover silage diet both during the growing and finishing phases.

Steers fed the control treatment had greater ($P<0.05$) hot carcass weights than steers fed the baled stover diet either during the growing phase alone or both during the growing and finishing phases or fed the untreated stover silage diet both during the growing phase (Table 4). But hot carcass weights did not differ among steers fed the CaO-treated stover silage during the growing and total feeding period, the untreated stover silage during the total feeding period, and the control treatment.

As a result of the hot carcass weights, steers fed the control treatment had greater ($P<0.05$) dressing percentages than steers fed the baled stover diet either during the growing phase alone or both during the growing and finishing phases or fed the untreated stover silage diet during the growing phase. However, the dressing percentage did not differ between steers fed the control treatment or the CaO-treated stover silage diet during the growing phase or fed the baled stover, untreated stover silage, or CaO-treated stover silage diets during the total feeding period.

Backfat thickness did not differ between steers fed the control treatment or the CaO-treated stover diet over the total feeding period. Although it was planned to finish at equal backfat thicknesses, the backfat thicknesses of steers fed the control treatment or the CaO-treated stover diet over the feeding period were greater ($P<0.05$) than steers fed the other treatments. Furthermore, steers fed the untreated stover silage diet during the feeding period had greater ($P<0.05$) backfat thicknesses than steers fed the untreated stover silage only during the growing phase.

The percentage of kidney, pelvic, and heart (KPH) fat of steers fed the CaO-treated stover silage diet either during the growing phase or total feeding period did not differ from those fed the control treatment. The percentage of KPH fat of steers fed the baled stover or untreated stover silage diets either during the growing phase or total feeding period were lower ($P<0.05$) than the control treatment. However, the KPH fat of steers fed the baled stover or untreated stover silage diets during the total feeding period did not differ from steers fed the CaO-treated stover silage diet either during the growing phase or total feeding period.

Ribeye area did not differ between treatments. However, the ribeye area per 100 lb of bodyweight of steers fed the baled stover diet during the growing phase or total feeding period or the untreated stover silage diet during the total feeding period were greater ($P<0.05$) than steers fed the control treatment. But the ribeye area per 100 lb of bodyweight of steers fed the CaO-treated stover silage during the growing phase or total feeding period or the untreated stover silage during the growing phase did not differ from steers fed the control treatment.

Although the mean carcass quality grade was greater than low choice (marbling score = small), the mean marbling score of steers fed the control treatment was greater ($P<0.05$) than steers in any other treatment. There were no differences in the carcass quality score between any of the treatments in which corn stover was fed at 20% of the diet either during the growing phase or the total feeding period. The calculated yield grade of steers fed the control treatment or the CaO-treated stover silage diet during the entire feeding period were greater ($P<0.05$) than any other treatment. Similarly, the plant yield grade of steers fed the control treatment or the CaO-treated stover silage diet during the entire feeding period were greater ($P<0.05$) than steers fed the baled stover or untreated stover silage diets during either the growing phase or total feeding period.

An economic analysis of the performance and carcass results of this study is shown in Table 5. Cost of production and net return per head was sensitive to grain price in this analysis. When corn was priced at $4 per bushel the conventional control treatment and the CaO treated stover diets offered the lowest cost of production and most net return. Stover systems, switched to the control at 1000 pounds were generally the least economical in this study, and those treatments where stover was fed at 20% of the diet throughout were intermediate in costs and returns. As corn price increased to $5 or $6 per bushel, the stover-based systems become more competitive, with the CaO-treated stover treatment, fed at 20% throughout the feeding period, being the most profitable.

Conclusions

Treatment of high moisture corn stover with calcium oxide at 5% of the stover dry matter will increase its digestibility. Thus, calcium oxide-treated stover may be fed at up to 20% of the diet dry matter with modified distillers grains with solubles as a replacement for corn grain in feedlot diets during the entire feeding period without adversely affecting daily bodyweight gains or feed efficiency. Feeding the higher levels of forage will reduce carcass marbling score. The comparable body weight gains and feed efficiencies of steers fed diets containing 20% calcium oxide-treated stover silage to those fed 5% baled stover imply that calcium-oxide treated stover silage may be a cost-effective replacement for a portion of the corn in the diets of feedlot cattle. Economics of replacement of corn grain with a combination of distillers grains and treated corn stover become more favorable with increasing corn price. At certain times, distillers grains and other coproducts will be extremely price competitive to traditional commodities

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Table 1. Diets fed during the growing and finishing phases.

Ingredient	Treatments						
	Control	Baled stover-Control	Untreated stover silage-Control	CaO-treated stover silage-Control	Baled stover	Untreated stover Silage	CaO-treated stover silagel
	% of DM						
Growing diets							
Baled stover	5	20	0	0	20	0	0
Untreated stover silage	0	0	20	0	0	20	0
CaO-stover silage	0	0	0	20	0	0	20
Modified DGS	20	40	40	40	40	40	40
Corn	70	35	35	35	35	35	35
Vitamin-mineral supplement	5[a]	5[b]	5[b]	5[c]	5[b]	5[b]	5[c]
Finishing diets							
Baled stover	5	5	5	5	20	0	0
Untreated stover silage	0	0	0	0	0	20	0
CaO-stover silage	0	0	0	0	0	0	20
Modified DGS	20	20	20	20	40	40	40
Corn	70	70	70	70	35	35	35
Vitamin-mineral supplement	5[a]	5[a]	5[a]	5[a]	5[b]	5[b]	5[c]

[a]Supplement for Control diet: Corn grain, 60.51%; Limestone, 25.10%; Salt, 4.75%; Vitamin A premix, 2.02%; Trace mineral premix, 0.36%; Rumensin premix, 0.33%; and Urea, 5.9%.
[b]Supplement for Baled stover and Untreated stover silage diets: Corn grain, 63.77%; Limestone, 29.18%; Salt, 4.48%; Vitamin A premix, 1.91%; Trace mineral premix, 0.34%; and Rumensin premix, 0.31%.
[c]Supplement for CaO-treated stover silage diet: Corn grain, 93.19%; Salt, 4.34%; Vitamin A premix, 1.84%; Trace mineral premix, 0.33%; and Rumensin premix, 0.30%.

Table 2. Dry matter intake and the digestion coefficients of dry matter (DM), neutral detergent fiber (NDF), and acid detergent fiber (ADF) from diets containing baled stover, untreated stover silage, or CaO-treated stover silage diets.

Item	Diets		
	Baled stover	Untreated stover silage	CaO-treated stover silage
DMI, gm/day	678	676	665
Digestion coefficients, %			
DM	75.9[a]	75.5[a]	83.2[b]
NDF	70.8	68.7	81.7
ADF	62.5	62.7	75.9

[ab]Differences between means with difference superscripts are significant, $P < 0.05$.

Table 3. Body weights (BW), daily gains (ADG), dry matter intakes (DMI), and feed efficiencies of steers fed the baled stover, untreated stover silage, or CaO-treated stover silage diets during the growing and/or finishing phases.

Item	Treatments						
	Control	Baled stover-Control	Untreated stover silage-Control	CaO-treated stover silage-Control	Baled stover	Untreated stover silage	CaO-treated stover silage
BW, lb							
Initial	648	652	650	643	649	647	644
Finish	1362[a]	1292[b]	1312[bc]	1342[bc]	1305[bc]	1342[bc]	1347[bc]
Days on feed	183	195	195	195	195	195	183
ADG, lb/day							
Growing[e]	3.91[a]	3.29[b]	3.35[b]	3.77[a]	3.37[b]	3.42[b]	3.76[a]
Total	3.90[a]	3.28[b]	3.42[b]	3.59[c]	3.36[b]	3.56[c]	3.84[a]
DMI, lb DM/day							
Growing	18.86[a]	18.34[b]	16.71[c]	17.20[d]	18.28[b]	16.89[c]	17.17[d]
Total	21.28[a]	19.14[b]	18.56[b]	18.75[b]	20.97[a]	20.77[a]	19.98[c]
Feed/Gain							
Growing	4.83[ac]	5.59[b]	5.00[c]	4.56[a]	5.44[b]	4.95[c]	4.57[a]
Total	5.46[a]	5.84[b]	5.45[a]	5.23[ac]	6.24[d]	5.83[b]	5.20[c]

[abcd]Differences between means with different superscripts are significant, $P < 0.05$.
[e]Growing phase = 0 to 112 days.

Table 4. Carcass Characteristics of steers fed the baled stover, untreated stover silage, or CaO-treated stover silage diets during the growing and/or finishing phases.

Item	Treatments						
	Control	Bale stover-Control	Untreated stover silage-Control	CaO-treated stover silage-Control	Baled stover	Untreated stover silage	CaO-treated stover silage
Hot carcass wt., lb	837[a]	762[b]	788[bc]	815[ac]	794[c]	813[ac]	823[a]
Dressing %	61.5[a]	59.1[b]	60.1[bc]	60.7[ac]	60.8[ac]	60.6[ac]	61.1[ac]
Fat cover, in.	.53[a]	.36[bc]	.33[b]	.39[bc]	.36[bc]	.39[c]	.49[a]
KPH, %	2.33[a]	1.82[b]	1.79[b]	2.05[ab]	1.88[bc]	1.92[bc]	2.15[ac]
Ribeye area, in.^{2}	13.54	13.18	13.18	13.45	13.63	13.93	13.49
Ribeye, in^2/CWT	1.62[a]	1.74[b]	1.67[abc]	1.66[ac]	1.72[bc]	1.72[bc]	1.65[ac]
Marbling score	1088[a]	1006[b]	1025[b]	1027[b]	1008[b]	1028[b]	1027[b]
Yield grade							
Calculated	3.13[a]	2.44[b]	2.47[b]	2.67[b]	2.44[b]	2.50[b]	2.96[a]
Plant	2.63[a]	1.90[b]	1.99[b]	2.20[bc]	1.90[b]	2.00[b]	2.43[ac]

[abcd]Differences between means with different superscripts are significant, $P < 0.05$.
[e]Marbling score: Select = 800, Select+ = 900, Choice- = 1000, Choice = 1100, Choice+ = 1200; and Prime- = 1300.

Table 5. Economic analysis of steers fed the baled stover, untreated stover silage, or CaO-treated stover silage diets during the growing and/or finishing phases.

Item	Treatments						
	Control	Bale stover-Control	Untreated stover silage-Control	CaO-treated stover silage-Control	Baled stover	Untreated stover silage	CaO-treated stover silage
Feeder value, -$1.05/lb	$ 680.40	$ 684.60	$ 682.50	$ 675.15	$ 681.45	$ 679.35	$ 676.20
Non-feed cost -$0.45/d	$ 82.35	$ 87.75	$ 87.75	$ 87.75	$ 87.75	$ 87.75	$ 82.35
Feed cost/hd							
-$4/bu corn[a]	$ 314.01	$ 278.07	$ 273.59	$ 279.84	$ 282.90	$ 284.97	$ 265.16
-$5/bu corn[a]	$ 379.27	$ 331.63	$ 326.13	$ 332.70	$ 333.27	$ 334.87	$ 310.20
-$6/bu corn[a]	$ 445.30	$ 386.34	$ 379.78	$ 386.67	$ 385.28	$ 386.38	$ 356.70
Total cost/cwt gain							
-$4/bu corn[a]	$ 58.24	$ 65.61	$ 60.14	$ 56.50	$ 60.63	$ 58.07	$ 52.47
-$5/bu corn[a]	$ 67.83	$ 75.22	$ 68.89	$ 64.62	$ 68.87	$ 65.84	$ 59.27
-$6/bu corn[a]	$ 77.53	$ 85.04	$ 77.82	$ 72.92	$ 77.38	$ 73.86	$ 66.29
Carc. value[b]	$1276.65	$1135.71	$1186.57	$1225.74	$1186.91	$1215.42	$1231.86
Return/head							
-$4/bu corn[a]	$ 199.89	$ 85.29	$ 142.73	$ 183.00	$ 134.81	$ 163.35	$ 208.16
-$5/bu corn[a]	$ 134.63	$ 31.73	$ 90.19	$ 130.14	$ 84.44	$ 113.46	$ 163.12
-$6/bu corn[a]	$ 68.60	$ -22.99	$ 36.54	$ 76.17	$ 32.43	$ 61.95	$ 116.61

[a]MDG prices were assumed to be 65% of corn price adjusted for dry matter. Other feed prices assumed were baled stover at $55/t, bagged non-treated stover at $59/t, bagged treated stover at $51/t and supplement at $400/t. Stover was priced at a similar dry matter value with additional costs of $8/ton added for bagging, and $7.50 per ton added for CaO treatment (bagging and treatment costs applied on an as-fed basis).
[b]Carcass grid prices assumed were USDA Choice, yield grade 3 base of $148/cwt. Discounts were $8.50 for Select, $20 for no-roll and $12.50 for yield grade 4. Premiums were 3.50 for CAB, $15 for Prime, $2 for yield grade 2 and $4 for yield grade 1.