Use of corn plant residues for cattle feed

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Take Home Message

Corn crop residues represent an abundant biomass that may be used to feed cattle. These residues are poor quality and can limit cattle performance in some cases. The way that residues are harvested and whether or not they are treated, affects how digestible they are and cattle performance when they are fed. Variations in performance and volatility of both the corn and cattle markets are all factors that affect what cattle producers can afford to pay for corn stover. Although performance and digestibility are enhanced with CaO treatment of corn crop residues, the additional cost is not always warranted. In addition, greater economic advantages may be realized when light weight cattle are fed corn crop residues as opposed to heavy cattle. Corn residues are one more feed option for cattle feeders to consider.

Introduction

Discussing ways to reduce input costs is often at the forefront of many cattle feeders minds. One way to reduce costs is to use alternative feeds (Felix, 2015). One such method includes feeding combinations of corn grain and ethanol co-products to finishing beef cattle; however, variable corn grain and ethanol co-products prices have led producers and nutritionists to seek *other* alternative feedstuffs. One alternative feed for cattle that has gained emerging attention in the United States in the past 5 years is harvested corn crop residues.

Corn crop residues are called by many names: corn stalks, corn stover, corn stalklage, or, simply, corn residues. Each slight twist on the name comes with minor characteristic changes; however, the end goal is the same: to use the forage in the field after corn grain harvest. Around 2009 to 2010, a shift in the U.S. literature on corn residues occurred. Prior to this time, much of the discussion surrounding corn residues referred to how best to graze them (Klopfenstein et al., 1987; Gutierrez-Ornelas and Klopfenstein, 1991; Vanderpol et al., 2009). Many articles included discussions on the agronomic properties, such as yields, soil compaction, etc., of crops that followed grazed residues (Sawyer and Mallarino, 2007; Tracy and Zhang, 2008). These factors vary greatly depending on soil type and structure of a given region. Although, grazing corn residues can still be an economically favorable production scenario, grazing may not always be a feasible option. In addition, it may be more economically advantageous to feed cattle in confinement. Thus, interest in the use of corn crop residues as stored forages began to increase around 2009 and 2010. According to feedlot surveys conducted by Vasconcelos and Galyean (2007) and Galyean and Gleghorn (2001), corn crop residues were not mentioned as primary roughage source for any of the surveyed cattle nutritionists prior to this time. However, the most recent survey suggested 29.2% of U.S. beef feed yards are using corn crop residues as the primary roughage source for finishing cattle (Samuelson et al., 2015).

Despite the knowledge surrounding and the use of corn crop residues in and by the U.S. industry, the published literature are largely extension articles (for example see Myers and Underwood, 1992; McCutcheon and Samples, 2002; Dejong-Hughes and Coulter, 2009). Several reasons for the relatively few peer-reviewed articles on the topic, when compared with other alternative feeds like distillers grains, for example, could be cited. However, chief among them are likely: 1) not enough funding for the applied research, 2) the variation in results that have been noted, and 3) lack of producer acceptance.

Corn crop residues are abundant, representing approximately 50% of the total biomass of the corn crop (McCutcheon and Samples, 2002; Sawyer and Mallarino, 2007). It has been estimated from anywhere from 75 million tons (Roth, 2014) to 232 million tons (Perlack et al., 2005) of corn residues are available for harvest every year in U.S. In Brazil, 15.69 million hectares of corn were harvested in 2014/15, producing, on average, 5,396 kg/ha (CONAB, 2016). Using a 50% of the total biomass of corn crop biomass available to be harvested, an estimated 42.33 million tons of corn residue were available to be harvested in 2015. Of course these numbers vary depending on how much residue is actually harvested and with what technique (discussed more below) and are far greater in the U.S. due to the greater corn production.

Although it may seem logical to harvest such an abundant feed resource, a state-wide survey from Iowa, the state with the greatest corn production in the U.S., in 2011 found that only 17% of farmers were even *interested* in harvesting their corn residue (Tyndall et al., 2011). The lack of interest in harvesting corn residue was a major shift from earlier surveys throughout the state that suggested as many as 74% of farmers would be interested in selling corn residues if they were profitable.

A key concern among farmers surveyed in Iowa (Tyndall et al., 2011) was the impact on the environment that corn residue removal may have. This suggests that the data on corn residue harvesting is still not making it back to producers. In fact, leaving just 30% of the corn residue on the field will diminish the impacts of removal on water and wind erosion (Gallagher and Baumes, 2012). However, surveyors felt the lack of acceptance or consideration of harvesting corn residue also centered on perceptions about harvest and transportation costs. If harvested though, there is a tremendous amount of potential corn residue available.

The objectives of these proceeding will be to outline the feeding of harvested corn residues, treated and untreated, and discuss the value addition of treatment in several corn residue scenarios.

Corn Crop Residues for Cattle

As previously mentioned, several articles have been published on the grazing of corn residues (Klopfenstein et al., 1987; Gutierrez-Ornelas and Klopfenstein, 1991; Sawyer and Mallarino, 2007; Tracy and Zhang, 2008; Vanderpol et al., 2009). One of the reasons that the focus on this abundant forage supply initially was on grazing is that grazed forages often represent the most economically viable source of feed in many beef production systems. To truly evaluate the truth of this statement, however, costs associated with harvesting and storage must be calculated based on performance and compared in both confined and grazed cattle systems.

When fed in confinement, how corn residues are harvested can greatly impact the yield (tonnage) and the moisture content of the residues (Atchison and Hettenhaus, 2003). Most corn residue harvested gathers stalks, leaves, cobs, and husks. The majority of the moisture resides in the corn stalk, which is also the greatest proportion of the residue (Myers and Underwood, 1992; Table 1). Thus, in order to ship “dry bales”, corn residues must remain in the field to dry down, which may not be the most economically advantageous harvesting method. This dried, baled corn residue (referred to as corn stover) is a mature, poor quality forage and often must be further processed, particularly when used as part of a total mixed ration for cattle fed in confinement.

Table 1: Corn stover material distribution DM during grain harvest

Stover Component	**Moisture, %**	**Percent of biomass, DM basis**
Stalk	70-75	50
Leaf	20-25	20
Cob	50-55	20
Husk	45-55	10

Source: Myers and Underwood, 1992

The poor quality of corn stover may have been the first limiting factor to its inclusion in cattle diets historically. At the time of traditional dry grain harvest, corn residue has about 60 to 70% NDF and 45 to 50% ADF (Duckworth et al., 2013). This is because the corn stover represents a mature forage source. With increasing forage maturity, cell wall composition changes, more structural carbohydrates are deposited within the cell wall: NDF concentrations increase, as do lignin concentrations. Jung and Vogel (1986) reviewed lignin inhibition of cell wall digestibility and there is a large body of literature discussing the negative effects of increasing ADF and NDF on DM and fiber digestibility (Allinson and Osbour, 1970; Smith et al., 1972; Cherney et al., 1993). Because of the poor quality of corn stover and the limitations on digestibility, recent U.S. efforts have attempted to increase the feeding value of corn stover through processing (Russell et al., 2011; Duckworth et al., 2014; Chapple et al., 2015).

One of the processing methods producers and nutritionist have used to improved feeding value of poor quality forages in the past is chemical treatment of the forage itself. Depending on the forage and the end goal, various chemical solutions that have been investigated for their effectiveness including sulfur dioxide (Ben-Ghedalia and Miron, 1984; Miron et al., 1990), ozone (Miron and Ben-Ghedalia, 1982; Bunting et al., 1984), and weak acids (Knappert et al., 1980; Silanikove and Levanon, 1987). Each of these chemicals has health risks or environmental concerns associated with it. Due to the abundance and safety, relative to some of the other agents used, CaO gained popularity as *the* corn residue treatment beginning in 2011. Calcium oxide is the dehydrated, powdered form of $Ca(OH)_2$ and can be added to a wet forage. Briefly summarized: yhe CaO corn stover treatment process involves wetting corn stover to 50% DM and then adding 5% CaO (DM basis). The treated corn stover must sit for at least one week before feeding to allow the chemical reaction to be effective.

During the process of chemical treatment, the chemicals dissolve the hydrogen bonds among lignin crust and the hemicellulose and cellulose (the fractions of the cell wall that can be digested by ruminant microorganisms). The treatment swells the cellulose microfibrils, which serves to partially break off and solubilize the hemicellulose polymers. This increases the surface area of cellulose, and the accessibility to hemicelluloses, and increases hydrolysis of both by rumen microbial cellulases (Kahar, 2013). In addition to its binding and inhibitory effects, lignin inhibits cellulose hydrolysis by irreversibly adsorbing cellulase enzymes. So, when lignin is separated from the cellulose/hemicellulose complex, it not only increases substrate availability, but also increases cellulase (enzymatic) activity (Lee, 1994). The end results is a reduction in total NDF concentrations of treated corn stover (Duckworth et al., 2014) and increased digestibility for cattle fed treated corn stover when compared to those fed untreated corn stover (Russell et al., 2011; Shreck et al., 2013; Duckworth et al., 2014; Chapple et al., 2015). However, even with increased digestibility, corn stover still contains inadequate energy and protein for growing cattle. Consequently, in most studies, a combination of corn stover (most often treated with 5% CaO, DM basis, and fed at 20% inclusion, DM basis) and distillers grains (usually wet or modified at 40% inclusion, DM basis) have been fed (Russell et al., 2011; Shreck et al., 2012; Shreck et al., 2013; Duckworth et al., 2014; Chapple et al., 2015). This feed became dubbed in U.S. industry circles as a “corn replacement feed”, referencing its potential ability to equally replace corn grain in the diet of growing cattle.

In growing cattle, increased digestibility of the diet (i.e. the CaO treatment of corn stover) should increase cattle performance. This often occurred when cattle fed CaO-treated corn stover were compared to cattle fed untreated corn stover in one of the aforementioned “corn replacement feed” diets. Russell et al. (2011) observed a 9.6% and 10.2% increase in DM digestibility for CaO-treated stover over baled and untreated, hydrated stover, respectively. In addition, Russell et al. (2011) reported 5% improvement in feed efficiency, driven by a reduction in DMI with no change in ADG, when steers fed 20% CaO-treated corn stover and 40% modified distillers grains with solubles (MWDGS; DM basis) were compared to steers fed the control that contained 70% corn and 20% MWDGS (DM basis). Shreck et al. (2011) concluded that feeding cattle CaO-treated corn stover at 20% of the diet DM improved IVDMD when compared with feeding an untreated corn stover control. A follow-up study in their lab compared CaO treatment of corn stover to that of CaO-treated corn cobs and wheat straw (Shreck et al., 2012). They reported that feeding CaO-treated corn stover and straw to cattle resulted in increased final BW, ADG, and feed efficiency when compared to feeding untreated corn stover and straw; furthermore, they observed no differences in ADG, DMI, or G:F between cattle fed the treated corn stover diet and those fed the corn-based control diet (46% corn grain, DM basis).

Positive responses have not always occurred, however. Although Duckworth et al. (2014) reported improvements in ruminal degradations of CaO corn stover relative to untreated corn stover, steers fed treated corn stover gained 0.26 kg/day less than steers fed untreated corn stover. This trial was unique because Duckworth et al. compared corn stover treatment *only*, all other dietary ingredients and inclusions were equal (i.e. 20% corn stover, treated or untreated; 40% modified distillers grain; 30% dry rolled corn; 10% vitamin mineral supplement, on a DM basis). Similarly, Chapple et al. (2015) reported an 8% increase in DMI and an 18% greater ADG in steers fed a corn-based diet (55% dry rolled corn and 5% untreated corn stover, DM basis) when compared to steers fed CaO-treated corn stover diets (20% stover and 40% modified distillers grains, DM basis).

Due to variations in performance and harvest technique in the aforementioned trials, if corn stover is treated prior to feeding, processing costs need to be added to the cost of corn stover if one wishes to compare true costs. Processing costs will vary depending on whether producers choose to use a custom processor or hire their own labor. All of the previous trials have fed mature, dry baled corn stover (harvested after dry corn grain) that was ground and wetted, prior to treatment with CaO. The need to grind corn stover bales prior to chemical processing represents an additional labor and energy cost when feeding CaO treated corn stover. Although performance results were not improved with corn stover feeding, Chapple et al. (2015) concluded that feeding treated corn stover yielded a significant reduction in total feed costs compared to cattle finished on a corn based diet. Improtantly, the authors did not feed an untreated corn stover control in this experiment and meant only to compare the corn replacement feed technology of the time that was being advocated.

Costs associated with treatment increase the CaO treated corn stover price over ground wetted corn stover. As mentioned previously, Duckworth et al. (2014) reported improvement in ADG when corn stover was simply wetted and bagged, suggesting the additional chemical treatment may not be entirely necessary. The processes used to simply bag wetted corn can vary as well though.

Traditional corn stover harvest may include a one-, two-, or three-pass technique. One pass techniques involves more expensive equipment and may slow corn harvest (Vadas and Digman, 2013). It has been suggested that one-pass harvesting, harvesting corn and stover at the same time, may be economically viable, yielding R$255.00/hectare ($1.00 = R$3.44) for farmers (Atchison and Hettenhaus, 2003). Two-pass technique involves more common equipment and may be accomplished with less cost than the three-pass technique. However, variations in these harvest techniques can also greatly impact the yield (tonnage) and the moisture content of the residues (Atchison and Hettenhaus, 2003).

Because of the variable responses and the cost of CaO treatment, Carvalho et al. (2016) compared differences in harvest window of corn residues instead of chemical treatment. These researchers hypothesized that corn stover harvested at high moisture corn harvest would be more economical that corn stover harvested at dry corn harvest due to changes in labor costs associated with a three-pass harvest technique and improvements in growth performance when “immature” corn stover (that harvested after high moisture corn) was fed to cattle. Thus, Carvalho et al. (2016) harvested the high moisture corn residues (also referred to as corn stalklage) after high moisture corn grain by raking windrows after the combines and harvesting the residue with a silage wagon so that it did not have to be baled and then ground. Moisture of the corn residues with this harvest method was ~45% DM and no water needed to be added. In addition, due to the variable results with CaO treatment and the desire to test maturity response, Carvalho et al. (2016) analyzed untreated forages, thus, the additional costs associated with CaO treatment were negated. One of the primary reasons to adjust harvest technique was cost. While baling stover is an expense, one can usually get a dry ton of stover out of the field and baled for close to R$156.03 (Ag Decision Maker, 2015). However, the grinding and treatment costs to produce the CaO treated corn stover fed in many of the aforementioned trials, greatly increases the price per ton. Such that if one feeds a CaO-treated corn stover that is rehydrated, has 5% CaO added, and is then bagged, the final cost per dry ton is closer to R$499.32. By comparison, the one-pass harvest technique costs were R$333.92/ton (dry). Cattle performance was monitored through the growing phase of this experiment. Diets were fed for 85 d, during the growing phase, and contained 25% corn plant residue, 30% modified distillers grain with solubles, 35% high moisture corn, and 10% supplement (DM basis). There were no treatments effects on ADG, DMI and G:F from d 0 to 85 when all cattle were compared as a single group. Nor were there effects of treatment on dry matter disappearance and NDF disappearance over time. Average NDF disappearance at 48 h were 27.4 and 30.6 % for stover harvested at dry corn harvest and stover harvested at high moisture corn harvest, respectively (Carvalho et al., 2016). However, strong differences were noted by block: with light weight cattle outperforming heavy weight cattle when fed the corn residue.

The block data become important when the whole system economics using corn residues are calculated. Because cattle performance also drives the price producers are able to pay for corn residues, greater animal performance, in particular ADG, yield a more profitable is the system. This is one of the reasons that harvesting corn residues and feeding it in a feedlot has become more widely practiced in the U.S. as opposed to just grazing corn residues. Evaluating the true cost of feedstuffs based off of their energy values can only be done if animal performance is known. Due to the associative effects of feeds in the rumen, book values can both over- and under-estimate the true value of feeds, affecting their economic advantage. The previous economic evaluations of corn residues (Felix and Carvalho, 2016) show they are most advantageous in a growing system where light weight cattle are fed. Book values for corn residues predict grazing ME to be 2.38 Mcal/kg with harvested ME closer to 1.99 Mcal/kg (NRC, 2000). However, using NRC (1996) equations, to backcalculate the true energy value for corn residues for growing cattle based on performance Russel et al. (2011) had 3.12 MCal ME/kg for corn stover and Carvalho et al. (2016) showed 2.94 Mcal ME/kg.

Conclusions

Because of these variations in performance, the bottom line economics must be used to determine the appropriate use of corn residue in cattle diets. Processing costs associated with dry, baled stover affect the “real” price of corn stover feeding in confinement. If corn residues are wetted and bagged in an ag bag after harvest, as opposed to being fed as dry ground stover, there appears to be little value to treatment. However, if corn stover is to be fed in a feedlot at 20% of the diet DM, it is better to wet it to 50% moisture and bag it versus feeding dried ground stover. In addition, timing of feeding corn residue in the system may be a valuable consideration. Cattle that fed corn residue only in the growing phase, and then finished on corn are more profitable than cattle fed corn residue during the finishing phase (Felix and Carvalho, 2016). Thus, the advantage to feeding corn residue during the growing phase suggests greater benefits to the use of corn residues in a backgrounding or growing program (light weight cattle) than throughout the finishing program.

One of the most challenging aspects of beef cattle nutrition is the ever variable economics of the industry itself. The storage, handling, and feasibility issues with corn stover are different for each system and cost within system should be analyzed in Brazilian systems. Special attention should also be given to the potential economic return to the producer before corn stover is incorporated in any beef system. As an industry, we continue to seek out new ways to remain economically profitable in the face of ever changing commodity prices.

Literature Cited

Ag Decision Maker. 2015. Iowa Farm Custom Rate Survey. IA State Univ. Ext. and Outreach. FM 1698. Online August 8, 2016. http://www.extension.iastate.edu/agdm/crops/pdf/a3-10.pdf

Allinson, D. W., and D. F. Osbourn. 1970. The cellulose-lignin complex in forages and its relationship to forage nutritive value. J. Agric. Sci., Camb. 74:23-26.

Atchison, J.E., and J.R. Hettenhaus. 2003. Innovation methods for corn stover collecting, handling, storing, and transportation. Nat. Ren. Energy Lab. Contract No. DE-AC36-99-GO10337. Online July 21, 2016 http://www.afdc.energy.gov/pdfs/33893.pdf

Ben-Ghedalia, D., and J. Miron. 1984. The response of wheat straw varieties to mild sulphur dioxide treatment. Anim. Feed. Sci. Technol. 10:269-276.

Bunting, L. D., C. R. Richardson, and R. W. Tock. 1984. Digestibility of ozone-treated sorghum stover by ruminants. J. Agric. Sci., Camb. 102:747-750.

Carvalho, P.H.V., W.T. Meteer, A.R. Schroeder, A. DiCostanzo, and T.L. Felix. 2016. Enhancing the feeding value of corn residues to improve beef cattle production. J. Anim. Sci. 94 (E-Supple 2): 159.

Chaudhry, A.S. 1999. Rumen degradadation in sacco in sheep of wheat straw treated with calcium oxide, sodium hydroxide and sodium hydroxide plus hydrogen peroxide. Anim. Feed Sci. Tech 83:313-323.

Chapple, W.P., M.J. Cecava, D.B. Faulkner, and T.L. Felix. 2015. J. Anim. Sci. 93: 4002-4011.

Cherney, D. J. R., J. H. Cherney, and R. F. Lucey. 1993. In vitro digestion kinetics and quality of perennial grasses as influenced by forage maturity. J. Dairy Sci. 76:790-797.

CONAB. 2016. Acompanhamento da Safra Brasileira (Graos). V. 3 – Safra 2015/16 - N.4. Jan. 2016. http://www.conab.gov.br/OlalaCMS/uploads/arquivos/16_01_12_09_00_46_boletim_graos_janeiro_2016.pdf Accessed 30 November 2016

Dejong-Hughes, J., and J. Coulter. 2009. Considerations for corn residue harvest in Minnesota. Univ. MN-Ext. Online July 21, 2016. http://www.extension.umn.edu/agriculture/corn/harvest/considerations-for-corn-residue-harvest/

Duckworth, M.J., A.R. Schroeder, D.W. Shike, D. B. Faulkner, and T. L. Felix. 2013. Effects of feeding calcium oxide on growth performance, carcass characteristics, and ruminal metabolism of cattle. Prof. Anim. Sci. 30:551-560.

Felix, T.L. 2015. Use of alternative feeds for beef cattle. 8. XIX Curso: Novos Enfoques na Produção e Reprodução de Bovinos. Uberlandia, MG, Brazil. March 19, 2015.

Felix, T.L., and P.H.V. Carvalho. 2016. Value consideration in variable corn residue scenarios. Mn. Nutrition Conf. Proc. September 22, 2016.

Gallagher, P.W., and H. Baumes. 2012. Biomass supply from corn residues: Estimate and critical review of procedures. USDA Ag Econ Rep #847.

Galyean, M.L., and J.F. Gleghorn. 2001. Summary of the 2000 Texas Tech University Consulting Nutritionist Survey. Texas Tech University, Dept. of Anim. and Food Sci., Burnett Center Internet Progress Report No. 12. Online July 29, 2016 at http://www.asft.ttu.edu/burnett_center/progress_reports/bc12.pdf

Gutierrez-Ornelas, E. and T.J. Klopfenstein. 1991. Diet composition and gains of protein-supplemented growing cattle grazing corn residues. J. Anim. Sci. 69:2187-2195.

Jung, H. G., and K. P. Vogel. 1986. Influence of lignin on digestibility of forage cell wall material. J. Anim. Sci. 62:1703-1712.

Kahar, P. 2013. Chap 4: Synergistic effects of pretreatment process on enzymatic digestion of rice straw for efficient ethanol fermentation. In: “Environmental Biotechnology – New Approaches and Prospective Applications”. Ed. M. Petre. Online July 25, 2016. http://www.intechopen.com/books/environmental-biotechnology-new-approaches-and-prospective-applications/synergistic-effects-of-pretreatment-process-on-enzymatic-digestion-of-rice-straw-for-efficient-ethan

Klopfenstein, T., L. Roth, S.F. Rivera, and M. Lewis. 1987. Corn residues in beef production systems. J. Anim. Sci. 65:1139-1148

Knappert, D., H. Grethlein, and A. Converse. 1980. Partial acid hydrolysis of cellulosic materials as a pretreatment for enzymatic hydrolysis. Biotech. and Bioeng. 22:1449-1463.

Lee, D., A. H. C. Yu, K. K. Y. Wong, and J. N. Saddler. 1994. Evaluation of the enzymatic susceptibility of cellulosic substrates using specific hydrolysis rates and enzyme adsorption. Appl. Biochem. Biotech 45/46:407-415.

Loerch, S. C. 1996. Limit-feeding corn as an alternative to hay for gestating beef cows. J. Anim. Sci. 74:1211.

McCutcheon, J. and D. Samples. 2002. Grazing Corn Residue. Ag and Nat Res. Fact Sheet ANR-10-02. Ohio State University Extension. Online July 21, 2016. http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=A41ABD7B6BD77F4CFB076822F2D0151A?doi=10.1.1.193.4195&rep=rep1&type=pdf

Miron, J., and D. Ben-Ghedalia. 1982. Effect of hydrolysing and oxidizing agents on the composition and degradation of wheat straw monosaccharides. Eur. J. Appl. Microbiol. Biotechnol. 15:83-87.

Miron, J., R. Solomon, E. Yosef, and D. Ben-Ghedalia. 1990. Carbohydrate digestibility and nitrogen metabolism in sheep fed untreated or sulphur dioxide-treated wheat straw and poultry litter. J. Agric. Sci., Camb. 114:115-121.

Myers, D., and J. Underwood. 1992. Harvesting Corn Residue. Agronomy Fact Sheet 003-92. Ohio State University Extension.

Perlack, R. D., L. L. Wright, A. F. Turhollow, R. L. Graham, B. J. Stokes, and D. C. Erbach. 2005. Biomass as feedstock for a bioenergy and bi-products industry: the technical feasibility of a billion-ton annual supply. ORNL/TM-2006/66. Oak Ridge National Laboratory, Oak Ridge, Tenn.

Roth, G. 2014. Corn stover for biofuel production. Online July 25, 2016 http://articles.extension.org/pages/26618/corn-stover-for-biofuel-production.

Russell, J. R., D. D. Loy, J. A. Anderson, and M. J. Cecava. 2011. Potential of chemically treated corn stover and modified distiller grains as a partial

replacement for corn grain in feedlot diets. ISU Anim. Ind. Rep. AS 665:ASL R2586.
Samuelson, K.L., M.E. Hubbert, M.L. Galyean, and C.A. Loest. 2016. Nutritional recommendations of feedlot consulting nutritionists: The 2015 New Mexico State and Texas Tech University survey. J. Anim. Sci. 94:2648-2663
Sawyer, J. and A. Mallarino. 2007. Nutrient removal when harvesting corn stover. p. 251-253. In: Integrated crop management. Iowa State Univ., Ames. Online July 21, 2016. http://www.ipm.iastate.edu/ipm/icm/2007/8-6/nutrients.html
Shreck, A. L., C. D. Buckner, G. E. Erickson, T. J. Klopfenstein, and M. J. Cecava. 2011. Digestibility of crop residues after chemical storage. Neb. Beef Cattle Rep. pp. 35-36.
Shreck, A. L., B. L. Nuttelman, W. A. Griffin, G. E. Erickson, T. J. Klopfenstein, and M. J. Cecava. 2012. Chemical treatment of low-quality forages to replace corn in cattle finishing diets. Neb. Beef Cattle Rep. pp. 106-107.
Shreck, A. L., J. L. Harding, G. E. Erickson, T. J. Klopfenstein, and M. J. Cecava. 2013. Evaluation of rumen metabolism and digestibility when treated crop residues are fed in cattle finishing diets. 2013 Neb. Beef Cattle Rep, pp. 58-59.
Silanikove, N., and D. Levanon. 1987. Inter-relationships between acidic and alkali treatments of cotton straw and wheat straw and their fibre chemical properties. J. Sci. Food. Agric. 38:117-124.
Smith, L. W., H. K. Goering, and C. H. Gordon. 1972. Relationships of forage compositions with rates of cell wall digestion and indigestibility of cell walls. J. Dairy Sci. 55:1140-1147.
Tracy, B.F., and Y. Shang. 2008. Soil compaction, corn yield response, and soil nutrient pool dynamics within integrated crop-livestock system in Illinois. Crop Sci. 48:1211–1218.
Tyndall, J.C., E.J. Berg, and J.P. Colletti. 2011. Corn stover as a biofuel feedstock in Iowa's bio-economy: An Iowa farmer survey. Biomass and Bioenergy 35:1485-1495.
Vadas, P.A., and M. F. Digman. 2013. Production costs of potential corn stover harvest and storage systems. Biomass Bioenergy 54:133–139. doi:10.1016/j.biombioe.2013.03.028
Vanderpol, K.J., G. E. Erickson, N. D. Robbins, L. L. Berger, C. B. Wilson, T. J. Klopfenstein, E. P. Stanisiewski, and G. F. Hartnell. 2005 Effects of grazing residues or feeding corn from a corn rootworm-protected hybrid (MON 863) compared with reference hybrids on animal performance and carcass characteristics. J. Anim. Sci. 83: 2826-2834
Vasconcelos, J.T., and M.L. Galyean. 2007. Nutritional recommendations of feedlot consulting nutritionists: The 2007 Texas Tech University survey. 85:2772-2781