EFFECTS OF CORN PROCESSING AND DIETARY WET CORN GLUTEN FEED ON NEWLY RECEIVED AND GROWING CATTLE

by

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Abstract

Effects of corn processing with or without the inclusion of wet corn gluten feed (WCGF) on growth and performance were analyzed in two experiments. Treatments for both experiments were a diet including 47% whole-shelled corn (WSC) with no WCGF (WSC/0WCGF), a diet including 29% WSC with 30% WCGF (WSC/30WCGF), a diet including 47% dry-rolled corn (DRC) with no WCGF (DRC/0WCGF), and a diet with 29% DRC with 30% WCGF (DRC/30WCGF). Exp. 1 used 279 crossbred calves (230 kg) that were allocated to treatments in a 2x2 factorial completely randomized block design. No corn processing effects (all $P > 0.31$) were observed. Final BW was increased when WCGF was included in the diet ($P = 0.03$). ADG was increased for diets with WCGF ($P = 0.03$). Efficiency was not affected by the incorporation of WCGF in the diet. Digestibility of DM ($P = 0.006$) and starch ($P = 0.009$) was increased by the dietary inclusion of WCGF. There were no benefits observed for processing corn, but including WCGF at 30% (DM) increased gains and overall performance. Exp. 2 was a digestibility experiment using 5 ruminally cannulated Holstein heifers (248 ± 13 kg BW) in a 4 × 4 Latin square with an additional animal that was administered the same treatment sequence as another heifer on trial. No corn processing effects were observed for DM, starch, and ADF intake (all $P \geq 0.09$). Dietary WCGF inclusion increased starch, non-starch and ADF intake (all $P \leq 0.01$). Digestibility of DM, starch, non-starch, and ADF was not affected by corn processing, but DM, non-starch, and ADF digestibility were increased by WCGF inclusion in the diet ($P \leq 0.03$). Ruminal pH was not affected by corn processing ($P = 0.90$) or dietary WCGF inclusion ($P = 0.09$). No corn × WCGF interactions were detected. There also was no difference among VFAs or total VFA concentration (all $P \geq 0.12$) for corn processing effects. Passage rate (%/h) and ruminal liquid volume was not affected by corn processing or dietary WCGF inclusion (all $P \geq 0.66$).

Key words: receiving cattle, whole corn, wet corn gluten feed

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I can do all things through Christ who strengthens me. Philippians 4:13

Chapter 1 - Review of Literature

Introduction

Formulated rations that are high in fiber and relatively low in starch have long been used as a means to start receiving and subsequently growing cattle in feed yards. Cereal grains, such as corn, and forages are used to begin a structured feeding regimen designed to encourage high levels of consumption as well as meet the nutritional requirements of growing beef cattle. Oftentimes light-weight receiving calves are under considerable stress and will respond differently to handling, feeding, and eating compared to older, less stressed cattle. Newly received cattle encounter physiological and psychological stress from weaning, transport, commingling, and food/water deprivation. In order to combat losses in performance as well as morbidity and mortality due to these aforementioned stresses it is crucial to get calves back on full feed in as minimal a time as possible. Diets that are high in fiber and low in starch typically will result in the lowest morbidity and mortality rates, however performance is generally meager (Lofgreen, 1988). Thus, formulating diets that not only encourage intake but increase performance is paramount.

Receiving and Growing Diets

Calves initially entering a feedlot environment are subjected to a multitude of new stimuli. Oftentimes these cattle have already endured plenty of stress and are more susceptible to digestive disturbances, respiratory illness, and chronic maladies. Loerch and Fluharty (1999) listed the following as the major stresses to receiving cattle: weaning, marketing, transport, and a new environment at arrival. Although necessary, weaning is the first time a calf is removed from its dam and no longer allowed to nurse; this adjustment causes a change in the way nutrients must be obtained, as well as digested. Typically weaned calves have had the benefit of being on pasture with their dam and have learned to graze to a certain extent. These calves are able to transition to a full grazing diet better than calves that have not been allowed to graze with their dam, although the stress of a new social structure and increased vocalization can depress their immune responses. Calves can also arrive without the benefit of being pre-weaned and are thus more disposed to common illnesses such as bovine respiratory disease complex (BRD) and various digestive problems (Rivera, 2005).

Low feed intakes of 1.5% BW daily, due to stress, are typically observed the first two weeks after arrival (Galyean and Hubbert, 1995). Nutritional deficiencies due to decreased feed intake in the first few weeks in a feedlot make correcting nutrient deficiencies problematic. Low nutrient intake can increase susceptibility to disease by compromising the ability of the animal's immune system to properly respond and combat disease (Cole, 1996). BRD is a bacterial/viral complex that is the leading cause of feedlot morbidity (NASS, 2007). When a calf's immune system is overwhelmed by stress it succumbs much more easily to a viral or bacterial attack. Lekeu (1996) states that there are four recognized grades of BRD; grade 1 is subclinical disease; grade 2, compensated clinical disease; grade 3, non-compensated clinical disease; and grade 4, irreversible clinical disease. Identifying animals as early in the progression of the disease as possible is critical to limiting performance losses. Not only do weaning and transport cause significant negative impacts on health and subsequent performance of receiving cattle, feedlot environment also plays a role (Loerch and Fluharty, 1999). Loerch and Fluharty (1999) list several stressors such as: mud, poorer air quality, manure, and a new social dominance order as causes of immune distress and increased digestive issues. Calves have to adapt to all of these new stresses as to learn to consume feed out of a bunk within a short period of time. Another novel experience for most newly arrived calves is learning to consume water out of a waterer (Galyean et al., 1999). With all of these stresses, well formulated receiving and growing diets are critical.

Digestive upsets can result from extended periods of time without feed and water while the animals are held and transported. Baldwin (1967) stated his research showed that total bacteria numbers in the rumen were decreased from 10 to 25% of normal levels after 48 hours of withholding feed and water. However, this data was later disputed by Fluharty et al. (1994) as they reported that viable total and cellulolytic ruminal bacteria levels were not considerably ($P > 0.10$) decreased by 24 hours of feed deprivation. Their research indicated that the ruminal microbial population was not negatively impacted in its capacity to digest substrate immediately following fasting due to weaning and/or trucking. Depriving receiving calves of feed and water for up to 72 hours, and hauling them for 8 hours did not decrease the concentration or viability of ruminal bacteria (Fluharty et al., 1994). What is clear from this research is that lowered dry matter intake (DMI) and poor performance should not be attributed to decreased bacterial numbers and digestive capacity. Instead, decreased ruminal volume, dry matter (DM), total weight of ruminal contents, protozoal numbers as well as a decrease in saliva production contribute to a reduction in DMI (Loerch and Fluharty, 1999). Unfamiliar feed ingredients and feeding systems coupled with a new pen social hierarchy can also discourage feed intake (Grandin, 1997). Immediately attempting to increase DMI in newly received calves is crucial in helping them fight BRD and digestive issues.

Tactics to increase intake in light-weight calves arriving at the feed yard range from basic management protocols, like creep feeding, to preconditioning programs implemented prior to arrival. Because DMI is lowered, increasing nutrient density is important (Fluharty et al., 1996). Preconditioned animals have the added benefit of already being familiar with bunk line feeding and are thus more apt to return to normal feed intake more quickly. Receiving calves that do not have previous experience with bunks and formulated rations need to be monitored closely to identify potential illness before they go entirely off feed (Lofgreen, 1978).

Role of Energy in Morbidity and Performance

Newly arrived cattle that are under large amounts of stress exhibit eating behaviors opposite of non-stressed cattle (Lofgreen, 1983). Lofgreen (1988) stated that stressed calves will choose to eat high energy-dense diets over less energy-dense ones. A stressed calf will select a higher concentrate diet than a non-stressed calf; this behavior is potentially harmful as increasing concentrate level in receiving diets is usually followed by elevated morbidity and acidosis occurrences. Increasing concentrate in the diet results in increased morbidity incidence, but cost per unit gain typically declines (Lofgreen, 1988). To combat high morbidity and mortality rates as a result of a high-concentrate diet, all-hay rations can be offered. Unfortunately, gain and overall performance is reduced on an all-forage ration compared to diets containing concentrates. Lofgreen (1988) also stated that calves are not able to compensate for poor performance during the receiving period in later feeding periods. Thus, it is beneficial to feed receiving calves for good performance as well as encouraging increased DMI.

Energy plays a central role in receiving diets for many reasons. For most common receiving diets, energy levels are manipulated by altering dietary roughage concentration. Because of this, the effects of energy intake are frequently confounded (Duff and Galyean 2006). In an attempt to separate the confounding effects of energy and roughage levels in the diet, Berry et al. (2004a, b) fed two levels of starch with two levels of roughage. They had high and low starch concentrations within each of two dietary roughage concentrations. Their results showed that energy concentration did not impact performance or morbidity. It is interesting to note that the calves fed the higher energy diets shed less bacterins than cattle on lower energy diets. Similarly, Fluharty and Loerch (1996) conducted a trial with newly weaned calves that had not been preconditioned. They found that as dietary concentrate increased from 70 to 85% that DMI increased. However average daily gain (ADG) and morbidity were not impacted by the proportion of concentrate. Immune response to stimuli is highly complex and requires energy to properly function; the immune system of energy-deficient animals is most likely compromised making those animals more prone to infection and poor performance (Tizard, 1996). Although difficult to fully realize the true impact of the relationship between energy intake and roughage concentration in receiving diets, it is clear from the research that high energy with lower roughage diets may be beneficial.

Role of Protein Concentration

Increased dietary crude protein (CP) concentration is needed in a receiving diet to meet the calf's protein requirement while DMI is decreased (Loerch and Fluharty, 1999). Calculating the amount of protein needed by newly arrived cattle can present challenges (Galyean, 1999). Factorial equations and the metabolizable protein system presented in the NRC (1984, 1996) can be used to estimate the amount of protein needed by beef calves. Because those systems rely heavily on BW and feed intake, estimates derived from them are not always dependable. As stated previously, receiving cattle typically have depressed energy intakes and are thus less likely to be able to effectively deposit protein. With loads of cattle that are experiencing varying levels of feed intake depression it is difficult to accurately determine the protein requirement. Using the NRC systems as well as historical feed intake data for various types and sources of cattle to estimate protein requirements could prove useful (Galyean, 1999). In an attempt to determine the necessary protein level in receiving diets Galyean et al. (1993) assigned long-hauled calves to three diets with increasing CP levels. The diets were fed for 42 days and consisted of 12, 14, or 16% CP. Daily gain and feed intake increased linearly as CP level increased. They reported higher morbidity on the 16% CP diet compared to the other two diets. Following the trial all calves were fed a common diet with 14% CP and 85% concentrate. The animals on the 12% CP diet from the previous trial compensated for decreased gain to the point that it was clear that dietary CP concentration in the receiving diet did not affect overall performance.

Increasing CP concentration in receiving diets appears to increase morbidity rates significantly (Galyean, 1993; Fluharty and Loerch, 1995). When looking at metabolizable protein (MP) and the relationship to performance in newly arrived cattle there is evidence that there is a negative effect on health with increasing MP levels. Nissen et al. (1989) fed several levels of MP (5.2, 6.4, 7.4, and 9.5%) and reported a linear increase in ADG as well as improved feed:gain with increasing dietary levels of MP. There was a linear decrease in the number of untreated cattle with increasing MP. An interesting point to mention here is that although morbidity rate appears to increase with CP level, overall performance of calves fed higher CP levels was equal to or better than overall performance of cattle fed lower CP levels. Galyean et al. (1999) proposed this may be due to increased performance by morbid calves being fed higher CP levels, or superior performance by healthy animals eating higher CP diets that compensated for increased morbidity. Duff and Galyean (2007), in a review of dietary CP in highly stressed receiving cattle diets, recommend additional research to identify the effects of CP concentration on immune function in stressed cattle.

Receiving and Growing Diet Ingredients

With many of the previously cited studies good results were observed with feeding a 50 to 75% concentrate/grain and hay diet. Selection of feedstuffs used in receiving and growing diets is a function of cost, location, and available facilities. Obviously economics plays the largest role in determining feed ingredients used. Another factor in selection of components for receiving diets is the data that shows stressed calves are more likely to prefer dry diets over corn silage-based diets (NRC, 1996). Thus, avoiding silage in diets for lightweight, newly-arrive cattle is recommended. There is some question as to whether this preference is due to the "wet" nature of silage or the fact that it is a fermented feed. Other feedstuffs such at wet corn gluten feed, distiller's grains, and wet brewer's grains may not discourage intake to the extent observed with feeding silage. Roughage concentration also must be considered. As roughage concentration is increased, morbidity decreases (Rivera et al., 2005; Duff and Galyean, 2007). However, the disadvantage in intake and ADG that is observed with high levels of roughage would likely counterbalance any positive effects on health. Rivera et al. (2005) performed an economic analysis that showed cattle that had been started on a 100% roughage diet would perform worse economically compared to cattle started on a 40% roughage diet. They believed that the benefits of lower morbidity counts would not make up the differences in intake and gain. Although there are numerous studies working with varying levels of concentrate and roughage, it is clear that for receiving cattle performance is improved on at least 40 to 50% concentrate diets (Berry et al., 2004a,b; Duff and Galyean, 2007; Gorocica-Buenfil and Loerch, 2005). Because many receiving diets are fed by small operators who may not have access to bulk handling facilities, there is a definite need for identifying easily handled ingredients that can meet the nutritional requirement posed by light-weight calves. Finally, it is obvious that a calf in positive energy balance and increasing feed intake quickly after arrival should be more able to resist a disease challenge and perform well throughout feeding (Loerch and Fluharty, 1999).

Corn in Receiving and Growing Diets

Returning newly arrived cattle to full feed is critical to reducing incidence of morbidity and ensuring good performance throughout feeding (Rivera, 2005). Diets consisting of 50 to 75% concentrate prove to be a decent balance between adequate roughage and enough energy to help the animal recover from stress and start to gain. Because fermented feeds, such as corn silage, seem to discourage intake in newly arrived cattle, another form of energy is needed in receiving diets. Corn is an obvious choice as its starch content is approximately 72 percent (Herrera-Saldana et al., 1990; Zinn, 1991; Larson et al., 1993). Corn also has positive palatability aspects that encourage intake. Corn is not the only cereal grain available for use in diets, but Herrera-Saldana et al. (1990) showed the smallest amount of variation in starch content occurred in corn, whereas other grains like wheat, sorghum, barley, and oats were more variable. With less variation in starch content diets are more consistent and there is then less risk of ruminal or digestive upset.

Starch as an Energy Source

The structure of a kernel of corn is key to its ability to be digested. The pericarp surrounds the germ and endosperm; within the endosperm is a layer that contains enzymes and enzyme inhibitors which are essential in digestion (Kotarski et al., 1992). Underneath the enzyme-containing layer is the endosperm which has a starchy protein-rich matrix. Below all of those more external layers lies the floury endosperm which has the highest concentration of starch that is not bound in a protein matrix; starch in the floury endosperm is the most vulnerable to processing and digestion (Kotarski et al., 1992). The starch found in corn is composed mainly of amylopectin and amylose. Amylopectin (α 1-4 and α 1-6 linkages) and amylose (α 1-4 linkages) proportions vary greatly among species and varieties of grain; amylose can range from 0 to 20% of total polysaccharides (Rooney and Pflugfelder, 1986). Along with the starch component of corn, there are small proportions of pectins and sugars that compose the non-structural carbohydrate fraction. The vast majority of ruminal digestion of starch is accomplished by bacteria.

Ruminal Starch Digestion

Starch digesting ruminal bacteria adhere to particles of grain and colonize. These bacteria produce endo- and exo-enzymes that hydrolyze the α 1-4 and α 1-6 bonds of amylose and amylopectin (Galyean et al., 1979). Because not all bacteria have a complete array of digestive enzymes, integration among bacterial species is required for maximal starch digestion (Huntington, 1997). Ruminal protozoa and fungi also play roles in the digestion of corn grain. Protozoa can ingest and digest starch granules, as well as predate on starch hydrolyzing bacteria. Mendoza et al. (1993) found that the rate and extent of ruminal starch digestion was increased when protozoa were eliminated. They attributed this to two factors: the first, starch is more fully digested by colonizing bacteria than when it is digested by protozoa, and secondly, because protozoa predate on bacteria more bacteria survive and are able to digest starch when protozoa are missing from the rumen. Fungi may play a small, but useful, role by creating lesions in the surface of feed allowing for better bacterial attachment (McAllister et al., 1994). The pericarp is highly resistant to digestion because it is very difficult for bacteria to attach to the surface, making unaltered whole grains nearly impossible to digest for ruminants. Processed grains that have the pericarp broken or removed allow for increased digestibility of the starch by providing opportunity for bacterial attachment to starch granules (Huntington, 1997). Although there exists numerous ways to process grains to elicit physical and chemical changes to improve starch digestion, the cost of the ration increases with increased processing of ingredients. Although there does not seem to be a strong relationship between starch intake and subsequent ruminal digestibility, thus leading to the conclusion that there is no clear limit in the ability of the rumen to digest starch, there are plenty of conditions caused by excessive starch consumption (Huntington, 1997). Bloat, liver abscesses, and acidosis result from exceptionally rapid fermentation of starch to organic acids. So there stands a paradox of attempting to increase digestibility of grain starch while not making starch too available for microbial degradation.

Postruminal Starch Digestion

Digestibility of whole corn is 58.9% in the rumen and 91.7% for the total tract (Owens et al., 1986). Approximately 5 to 20% of starch is digested postruminally. The majority of postruminal digestion of starch occurs in the small intestine (Ramirez, 1985; Streeter et al., 1989, 1991). According to Huntington (1997), enzymatic digestion of starch in the ruminant small intestine proceeds similarly to other species. The pancreas secretes α-amylase, which hydrolyzes the starch's amylose and amylopectin into limit dextrins and linear oligosaccharides made up of two or three glucose units (Harmon, 1993). Hydrolysis of starch in the small intestine is then completed by enzymes on the brush border membrane of the intestinal microvilli (surface oligosaccharidases) (Harmon, 1992). Harmon (1992) reported intestinal digestibilities of starch in receiving and growing weight calves ranged from 17.3 to 84.9% of starch entering the duodenum. Similar ranges have been corroborated in several other studies (Owens et al., 1986; Kreikemeier et al., 1990; Hill et. al. 1991). All of these studies acknowledged lack of adequate pancreatic amylase activity as the principal reason that there was not total digestion of starch in the small intestine. Although absorption and metabolism of glucose seem to be more energetically efficient compared to fermentation and absorption of organic acids (Owens et al., 1986), Harmon (1993) concluded that secretion of starch digesting enzymes respond more to the amount of energy consumed than to the amount of dietary starch.

Mastication of Whole Grains

Light-weight, younger cattle are able to efficiently "process" whole corn kernels through mastication that damages the pericarp to allow bacterial attachment (Lofgreen et al., 1988). The process of chewing breaks the pericarp of the corn kernel, releases soluble nutrients for fermentation, and exposes the inner portions of feed to microbial attack (Beauchemin et al., 1994). Another key activity involved with mastication is the insalivation of feed that helps form a bolus to permit swallowing (Pond et al., 1984). Research conducted by Beauchemin et al. (1994) looked at the effects of mastication on the physical breakdown and ruminal digestion of whole cereal grains by cattle. They reported that eating time per day and per kilogram of DM was greater for whole corn diets compared to other grains fed. The increase in eating time for the whole corn diets was due to an increase in number of chews per kilogram of DM. They did not observe significant differences in rumen pH of whole corn fed cattle compared to rumen pH of cattle on other whole grain diets, and only 50% of the retained corn kernels in the feces were whole (compared to more than 75% of retained kernels in the feces for barley and wheat). Compared with other whole grains (wheat, barley, oats), corn kernels are larger and seem to require more chewing during eating to form a bolus and allow swallowing. Because of the extended chewing time, a limited amount of whole corn bypassed digestion and ended up in feces as wasted energy. Interestingly, this study also looked at the difference between whole corn and corn that had been quartered; because of the physical damage sustained by whole corn during eating, ruminal disappearance of DM, starch and CP was extensive and exceeded that of quartered grains. Unlike high-forage diets where the length of time spent eating and ruminating increases with the concentration of fiber in the diet, fiber content of grain diets was not related to chewing time (Woodford et al., 1986; Beauchemin et al., 1994). Another potential benefit of feeding whole grain corn, also related to the increased chewing time, is an increase in retention time in the rumen. The longer the digesta can remain in the rumen, the more complete digestion will be. The saliva produced during mastication and swallowed also acts as a ruminal buffer. The extensive damage sustained by whole corn kernels may also explain the similarity of feed:gain ratios in cattle fed whole or rolled corn (Chester-Jones and Zeigler, 1991). Saving processing costs by feeding whole corn can be more economical, and feeding whole corn does not negatively impact health or digestion relative to feeding whole corn.

Whole versus Dry-Rolled Corn

Research conclusions comparing the use of whole corn and rolled corn in receiving and growing diets are varied and conflicting. In some research corn processing is reported to increase starch digestibility (Galyean et al., 1979; Turgeon et al., 1983) and feedlot performance (Zinn et al., 2002). A review conducted by Owens et al. (1997) looked at numerous studies involving grain processing and subsequent digestibilities; they concluded that processing corn (grinding) did not improve starch digestibility and performance. A commonly proposed thought is that receiving and growing cattle are more prone to thoroughly masticating the diet and thus “process” the corn (Nicholson et al., 1971; Morgan and Campling, 1978). In order to determine if there is an interaction between cattle age and diet digestibility and feedlot performance, Gorocica-Buenfil and Loerch (2005) ran three trials using cattle of varying weights and diets. They also wanted to determine if there was any effect of forage level and corn processing on diet digestibility and performance. The first trial compared the digestibility of a whole corn diet to a ground corn diet (8% hay DM). Diets were fed to weanlings or yearlings to identify any difference age may have. The second trial attempted to determine the effects of forage level and grain processing method on feedlot performance and carcass characteristics. The final trial looked at diet digestibility of whole and processed corn in diets that had either high (18.2% DM corn silage) or low (5.2% DM corn silage) forage content. Trial 2 and 3 both used the same diet formulations. Results from the first trial showed there was no interaction between cattle age and corn processing. Diet DM, organic matter (OM), starch, CP, ADF and NDF digestibility were not affected by age or corn processing. The authors proposed the differences in cattle age between weanlings and yearlings may not have been sufficient enough to allow for expression of chewing differences, or chewing capacity of both ages was good enough to allow for similar starch digestibility. Cattle age did not affect fecal starch concentration, and differences in starch digestibility were not significant. Results for the second trial showed no interaction between forage level and corn processing for overall feedlot performance and carcass characteristics. Final ADG and feed efficiency was not affected by forage level or grain processing treatment. Importantly, overall feed efficiency for trial 2 was similar for both whole corn and rolled corn diets. Results from trial 3 indicated no significant interaction between forage level and corn processing. From these three experiments the authors concluded that whole corn may partially substitute for forage in feedlot diets due to its physical structure, and the combined effects of high forage and whole corn may lead to a better ruminal environment for fiber digestion. Feeding whole corn may also decrease cumulative acid insult to the rumen which over time will impair efficiency and productivity.

Whole corn can be included successfully in receiving and growing diets without insult to rumen health or productivity (Reinhardt et al., 1998). The economic benefits of decreasing morbidity, eliminating processing costs, and reducing forage in the diet simply by using whole corn are marked and significant. Another desirable outcome of using whole corn is the positive impact on rumen health (Gorocica-Buenfil and Loerch, 2005). This more recent research corroborates trials conducted by Lofgreen et al. (1988) that found whole-shell corn can be used with forage in receiving and growing diets. This data supports that the additional costs associated with grinding corn may not be justified. With all of this data in mind it seems appropriate to conclude that feeding whole corn with roughage to receiving and growing cattle is cost effective and will promote healthier animals.

Ethanol By-Products in Beef Diets

The growth of the ethanol industry has been fueled by the desire to source local, "cleaner" energy. The demand for corn has increased exponentially and has driven the availability of lower cost corn by-products ever higher. Using these by-products in ruminant diets makes economic sense because there is an excess supply, as well as being an inexpensive source of protein and energy. The energy supplied comes in the form of fat, fermentable fiber, and intestinally digestible protein. Using ethanol by-products can be economic as well as beneficial for animal digestibility and thus overall animal performance (Cordes et al., 1988).

Wet Milling By-Products

Wet milling is one of two techniques used to produce ethanol (Kalscheur et al., 2008). The corn wet milling process consists of steeping the corn kernel in water and sulfur dioxide to soften the pericarp and cuticle. The steep water is then drained and the germ is separated out of the slurry that is left after the steeping step. The oil is removed from the germ and the germ is then ground so as to release the starch and gluten from the fiber in the kernel. The last stage consists of centrifuging the mill starch to separate the gluten. The remaining starch will still contain 1 to 2% protein and must be washed and diluted further to achieve a high quality, 99.5% pure corn starch product (Blasi et al., 2001). Feed by-products of the wet milling process make up approximately 30% of the raw corn input. Of this 30%, 24% is made into corn gluten feed with the remaining 6% ending up as corn gluten meal. Almost two-thirds of the corn kernel is converted into starch with about 4% making corn oil (Johnson and May, 2003).

There are several by-products of the wet milling process that are utilized in ruminant diets. Corn bran, corn gluten feed, corn gluten meal, corn germ meal, and condensed fermented corn extractives are all by-products that are regularly used in the feed industry (Loy and Wright, 2003).

Wet Corn Gluten Feed

Wet corn gluten feed (WCGF) is comprised of the remnants of the kernel after the starch, gluten, and germ have been removed; it is the product of combining the remaining corn bran with steep liquor. Nutrient profile can vary widely depending on amount and type of steep liquor added to the bran (Wickersham et al., 2004). The normal ratio of bran to steep is 2/3 to 1/3 in the final WCGF product (Blasi et al., 2001). The predominant protein is rumen-degradable (RDP), and it is thought WCGF contains a similar percentage of the CP as RDP as soybean meal (Kalscheur et al., 2008). A major benefit of using WCGF in ruminant diets is the availability of fermentable fiber as an energy source. In terms of energy value, WCGF's value relative to corn increases in high-roughage diets because it provides energy without the negative associative effects on fiber digestion (Blasi et al., 2001). The use of WCGF in high forage (more than 50% DM) receiving and growing diets increases total digestibility and thus overall performance (Cordes et al., 1988). With the majority of its composition being bran, WCGF is high in fiber content. Montgomery et al. (2000) reported effectively replacing roughage in the diet of limit-fed growing steers with WCGF (fed at 40% of DM). Storing WCGF can present challenges as it is a wet product that can easily spoil if proper precautions are not taken. Wet corn gluten feed can stay viable for up to 7 days in hot weather, and approximately two weeks in cold weather (Blasi et al., 2001). Timely feeding of WCGF is essential to guarantee accurate DM and nutrient profiles. Wet corn gluten feed is an excellent source of energy in the form of fermentable fiber, roughage replacement, and diet conditioner.

Wet Corn Gluten Feed in Diets

A plethora of research exists on the use of WCGF in finishing diets. Most of these trials examined the value of WCGF relative to dry-rolled corn or steam-flaked corn in common finishing diets (McCoy et al., 1997, 1998; Montgomery et al. 2004; Farran et al., 2006; Loe et al., 2006). Research conducted by Loe et al. (2006) found that inclusion of WCGF in diets that contained high fiber improved ADG and increased DMI. An increase in ruminal pH and total tract digestibility of OM, NDF and starch was observed when WCGF was added to a diet containing steam-flaked corn (Montgomery et al., 2004). Because WCGF has a low starch concentration and is a source of fermentable fiber, conventional levels of roughage may not be necessary when WCGF is included in diets. Roughage in the diet helps balance rumen pH by increaseing saliva production, slowing rate of fermentation, and encouraging growth of fibrolytic bacteria. Roughage also promotes stimulation of rumen epithelial tissue thus keeping it healthy (Sindt et al., 2003). Most forms of roughage, alfalfa hay for instance, are expensive because of their predilection to shrink as well as their high cost per unit energy provided (Stock et al., 2000). Several trials indicated that ruminal pH was either not changed or increased with the addition of WCGF (Krehbiel et al., 1995; Sindt et al., 2003; Montgomery et al., 2004). Farran et al. (2006) tried to determine if WCGF could be used as an energy source, reduce the need for alfalfa hay, and aid in control of acidosis. Cattle on diets that received WCGF had an increase in DMI, as well as improved carcass characteristics (greater REA and 12^{th} rib fat thickness). As alfalfa hay was removed from the diet and replaced with WCGF feed conversion improved. The authors concluded that alfalfa hay has less value when diets contain WCGF, and the improved carcass characteristics presumably resulted from a decrease in ruminal starch load and thus a decrease in ruminal acidosis incidence.

Few trials have evaluated the impact of WCGF in receiving and growing diets, as finishing diets represent the majority of time on feed. The problem with trying to draw conclusions from finishing diet trials is the lack of similarity to receiving and growing diets, as well as the difference in nutrient requirements and feeding regimens of finishing cattle.

A trial conducted by McCoy et al. (1997) evaluated ruminal metabolism and digestibility of dry-rolled corn (DRC), WCGF, and alfalfa hay in receiving diets. Wet corn gluten feed is lower in starch compared to DRC (26 vs. 72% DM); WCGF is higher in NDF (44 vs. 12% DM), and the crude protein (CP) content of WCGF is higher than DRC (15-20 vs. 9% DM). The results from their research were as follows: no difference existed for DMI between DRC and WCGF diets, ruminal passage rate was faster for the WCGF diet, ruminal pH and ruminal concentration of NH_3-N, acetate, propionate, butyrate, and total VFA were not different. Crude protein and starch disappearance rates were faster for the WCGF diet compared to the DRC diet. The faster passage rate of WCGF is likely due to the smaller particle size and increased rumination activity. Residual protein or starch associated with the bran fraction of WCGF may be more disposed to microbial degradation compared with the starch/protein matrix of DRC, thus leading to a faster rate of CP and starch disappearance. Apparent total tract digestibility of DM, starch, and NDF was greater for the WCGF diet. They concluded that WCGF in receiving diets is digested extensively in the rumen, and by replacing DRC with WCGF that it might be possible to improve feed efficiency.

Using WCGF in receiving and growing diets has the potential to increase DMI, improve feed : gain, decrease incidence of ruminal acidosis, and allow for some removal of roughage from the diet. The metabolic benefits observed when feeding WCGF lend it to being a good ingredient to use in receiving and growing diets. By combining whole corn and WCGF, improved health, gain, and long term performance may be possible.

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Chapter 2 - Effects of Corn Processing and Dietary Wet Corn Gluten Feed Inclusion on Newly Received and Growing Cattle

Introduction

Newly arrived feedlot cattle present numerous challenges and are considered to be the most difficult type of fed-cattle to manage. Typically, receiving cattle are highly stressed and have had feed withheld for a significant amount of time. In an attempt to limit losses in performance due to morbidity and mortality, receiving cattle are fed diets that are high in fiber and low in starch (Lofgreen, 1988). Low feed intakes of 1.5% of BW daily are often observed in the 2 wk after arrival at a feed yard, which compounds the issue of returning cattle to full feed (Galyean and Hubbert, 1995). Low feed intake hinders a manager's ability to effectively control and prevent morbidity. Although high forage and low starch diets minimize morbidity, energy intake is still less than with higher starch diets, and calves are not typically able to compensate for poor performance during the receiving period in later feeding programs (Lofgreen, 1988).

Formulating a ration that is nutrient dense, to accommodate for lowered intakes, and cost effective is essential. Corn is an obvious choice for cattle rations because it is high in starch, easily digested, and commonly available. Previous research conducted to compare feeding whole-shelled corn versus dry-rolled corn found that receiving and growing cattle are adept at thoroughly masticating the diet, thus removing the need to process corn prior to incorporating it in a diet (Nicholson et al., 1971; Morgan and Campling, 1978). Wet corn gluten feed (WCGF) is another feedstuff that is an excellent choice for growing cattle. A major benefit of using WCGF is the availability of fermentable fiber as an energy source. The energy value of WCGF relative to corn increases in high-roughage diets because it provides energy without the negative associative effects on fiber digestion (Blasi et al., 2001). In addition, with WCGF being mainly bran it is possible to replace roughage in the diet with WCGF. By combining whole corn and WCGF, improved gain, lower feed costs, and enhanced long term performance may be possible.

The objective of these 2 experiments was to determine if there were any effects of corn processing (whole-shelled or dry-rolled), dietary WCGF inclusion, or their interaction on performance and digestibility by receiving and growing cattle.

Materials and Methods

All procedures involving the use of animals were approved by the Kansas State University Institutional Animal Care and Use Committee.

Experiment 1. Receiving and Growing Cattle Performance Study

Two hundred seventy-nine crossbred steers (230 kg BW) assembled through commercial sale barn market facilities were used in a complete block design with a 2 × 2 factorial arrangement of treatments to evaluate effects of corn processing (whole-shelled versus dry-rolled) and WCGF inclusion (0 or 30% of dietary DM). Calves were fed twice daily for a total of 60 d. The same rations were fed for the entirety of the 60 d. The test diets (Table 2.1) were: whole-shelled corn (WSC) with no WCGF, WSC with 30% WCGF, dry-rolled corn (DRC) with no WCGF, and DRC with 30% WCGF. Rollers used to crack the DRC were set to comminute the corn kernel as little as possible while ensuring all kernels were cracked. All hay was ground through a 10-cm screen before feeding. Diets were designed to provide the same amount of alfalfa and prairie hay while removing and replacing corn with WCGF. Inclusion of 30% WCGF eliminated the use of molasses as a diet conditioner, decreased the amount of supplement fed, and decreased amount of corn in the diet. Diets without WCGF had 5% molasses to condition the total mixed ration. DRC replaced the entire amount of WSC in the diets.

All calves were blocked by truck (n = 3) and stratified by arrival weight to groups of 11 or 12 cattle, and groups were randomly assigned to pens. Twenty-four pens of equal size were used, which allowed for 6 pens per treatment. Each pen (9.1 × 15.2 m) was soil surfaced with a concrete fenceline bunk (9.1 m) that was coupled to a 3.6-m concrete apron.

The day after arrival (d 0), all calves were vaccinated for clostridial and viral diseases with: Reliant 4, a modified-live vaccine against infectious bovine rhinotracheitis (IBR), bovine virus diarrhea (BVD) and parainfluenza 3 (PI3), and killed vaccine against bovine respiratory syncytial virus (BRSV) (Merial Animal Health, Duluth, GA); Respishield HM, a killed antigen prevention of respiratory disease caused by *Mannheimia haemolytica* and *Pasteurella multocida* (Merial Animal Health); and Clostrishield 7, a 7-way modified-live vaccine against a broad spectrum of clostridial bacteria (Novartis Pharmaceuticals, East Hanover, NJ). On d 0, all calves were also dewormed with 5 mL 1% ivermectin wt/vol and 10% wt/vol clorsulon (Ivomec Plus, Merial Animal Health) and given a subcutaneous injection of 7.5 mL of Excede (200 mg centiofur equivalents (CE) per mL; Pfizer Animal Health, New York, NY). Cattle were revaccinated on d 14 with: Calvary 9 (broad-spectrum clostridial modified-live vaccine; Merck Animal Health, Summit, NJ), Bovishield Gold 5 (modified live virus strains of IBR, BVD (Types 1 and 2), PI3, and BRSV viruses; Pfizer Animal Health), Respishield HM, and treated with 8 mL of CyLence (1% wt/vol of cyfluthrin; Bayer, Shawnee Mission, KS).

Cattle were weighed at initial processing (d 0), during revaccination (d 14), on d 28, and upon completion of the study (d 60). Fecal grab samples were collected from each animal and composited by pen on d 14, 28, and 60. Feed samples of each total mixed diet were collected weekly. The amount of feed delivered to each pen was recorded on a daily basis. Ground feed samples (1-mm screen) and partially dried (55°C) and ground (1-mm screen) fecal samples were analyzed for DM (105°C), starch (Herrera-Saldana and Huber, 1989 with glucose measured as described by Gochman et al., 1972), and ADIA (Undersander et al., 1993). Total tract digestibilities were calculated with reference to ADIA as the digestion marker. Nitrogen, calcium, and phosphorus were analyzed by methods presented by AOAC (1997). Animals exhibiting clinical signs of illness were identified and treated based on symptoms and then returned to their original pen.

Experiment 2. Digestibility Study

An experiment was conducted using 5 ruminally cannulated Holstein heifers (248 ± 13 kg initial BW) to evaluate diet digestibility and ruminal parameters. The experiment was designed as a 4 × 4 Latin square with the additional heifer given the same treatment sequence as another heifer. Diets were the same as for Exp. 1 except melegestrol acetate was added to prevent estrus. Heifers were housed in individual stalls (3.7 × 3.7 m) in a temperature-controlled barn (10 to 21°C). Heifers were allowed free movement in their stalls and only restrained during sample collection. Four consecutive 15-d periods were used, each consisting of 10 d for diet adaptation, 4 d for fecal collections, and 1 d for ruminal fluid sampling.

Heifers were fed once daily at 0800 h. Feed was provided for ad libitum intake, feed calls were designed to allow at least 10% feed refusals. Feed samples were collected on d 10 through 14 and composited for each heifer in each period. Feed refusals were collected at 0700 h, dried at 55°C and ground through a 1-mm screen. On d 4 through 14, 10 g of Cr_2O_3 was mixed by hand into the diet of each heifer immediately before feeding. On d 11 through 14, fecal samples were obtained from the rectum of the heifers 3 times daily (every 8 h), with the sampling time advanced by 2 h each day so that samples were obtained at each 2-h interval after feeding. Feed refusals and fecal samples were composited within each period for each heifer. Fecal samples were dried at 55°C, and then ground through a 1-mm screen. Composited feed and fecal samples were analyzed for DM, starch by the method of Herrera-Saldana and Huber (1989), and ADF content (Van Soest et al., 1991, Undersander et al., 1993) with ash correction. Cr_2O_3 was analyzed by atomic absorption spectrophotometry (Williams et al., 1962).

On d 15 of each period, ruminal fluid samples (20 mL) were collected beginning immediately prior to feeding. Samples were strained through 4 layers of cheese cloth; pH of the strained ruminal fluid was immediately measured with a portable pH meter (Orion, Beverly, MA), after which 16 mL of the strained ruminal fluid was added to 4 mL of 25% (wt/vol) *m*-phosphoric acid and frozen at -20°C. Immediately after the 0-h sampling, CoEDTA (providing 0.4 g of Co) solubilized in 200 mL water was dosed through the ruminal cannula (Uden et al., 1980). Ruminal fluid was subsequently sampled at 2, 4, 6, 8, 12, 18, and 24 h after CoEDTA dosing; samples were preserved as described above with an additional aliquot of strained rumen fluid retained for analysis of Co.

Collected rumen fluid was analyzed for volatile fatty acids, ammonia, and cobalt. Liquid passage rates were calculated from ruminal cobalt concentrations from 2 to 18 h after dosing of the Co-EDTA. For each heifer in each period, the natural logarithm of the cobalt concentration was linearly regressed against time using the nonlinear procedure of SAS to determine passage rate (negative slope of the regression); ruminal liquid volume was calculated as the cobalt dose/$e^{(\text{intercept from the regression})}$.

Statistical Analyses

Data for Exp. 1 were analyzed using MIXED procedure of SAS (version 9.1.3; SAS Inst. Inc., Cary, NC) including the fixed effects of corn, WCGF, and corn × WCGF, while the random effect was block.

For Exp. 2, data were analyzed as a Latin square with a factorial arrangement of treatments using the MIXED procedure of SAS. The statistical model included fixed effects of corn processing, WCGF inclusion, corn × WCGF, and period. Heifer was a random effect. Treatment means were calculated using the LSMEANS option. Ruminal fermentation parameters were analyzed as repeated measures with the model containing corn processing, WCGF, corn × WCGF, sampling time, time × corn processing, time × WCGF, time × corn processing × WCGF, and period. Heifer was included as a random term. The repeated term was time, and heifer × period served as the subject; the covariance structure was spatial power.

Results and Discussion

Experiment 1

Very low morbidity and no mortalitly was observed in this study. Only 1 respiratory illness and 3 bloats were observed (all receiving dry-rolled corn with no WCGF) and all 4 calves required only 1 treatment to recover.

No effects of corn processing were observed on intake ($P \geq 0.31$) (Table 2.2). Similarly, ADG was not affected by corn processing ($P \geq 0.50$). Feed efficiency likewise did not differ between the corn processing treatments ($P = 0.61$). This data agrees with research that light-weight cattle are able to effectively masticate and thus “process” corn (Lofgreen et al., 1988; Beauchemin et al., 1994). Our results also agree with research conducted by Gorocica-Buenfil and Loerch (2005). They presented digestibility data from a trial comparing diets containing WSC and DRC with 8% hay (DM). They observed no effects of corn processing on digestion of DM, OM, starch, CP, ADF, or NDF due to corn processing. These authors also concluded that WSC may partially substitute for forage in feedlot diets due to its physical structure, and the combined effects of higher forage and WSC may lead to a more conducive ruminal environment for fiber digestion. Reinhardt et al. (1998) published data demonstrating the successful use of WSC in receiving and growing diets without insult to rumen health or productivity.

There were several differences in performance when WCGF was incorporated into the diets (Table 2.2). Over the entire 60-d study, calves receiving diets with 30% WCGF gained more than calves fed diets without WCGF (P = 0.03). Also, DMI tended to be greater for calves fed diets with 30% WCGF over the 60-d trial (P = 0.11), with the effect predominantly observed between d 28 and 60 (P = 0.07). There was a corn × WCGF interaction detected for DMI between d 14 to 28 with the WCGF increasing intake when added to WSC diets but not when added to DRC diets; this pattern was similar, but less well defined (P = 0.19) between d 28 and 60. Interestingly, the improvement in ADG for calves fed WCGF appeared with the first 28 d of the trial, with the greatest response for improved ADG from d 0 to 14 (P = 0.08). This data agrees with results published by Loe et al. (2006); their research demonstrated that the inclusion of WCGF in diets that contained high fiber improved ADG and increased DMI. Addition of WCGF increased ADG early in the trial (d 0 to 14), but DMI was not increased until later in the feeding period (d 28 to 60). There was no apparent difference in overall efficiency with the inclusion of WCGF (P = 0.45); however, efficiencies tended (P = 0.07) to be improved by WCGF inclusion during the initial 14 d of the trial but numerically worsened during d 28 to 60.

Digestibility of DM was improved with dietary inclusion of WCGF ($P = 0.006$) and total tract starch digestibility was also increased when WCGF was fed ($P = 0.009$) (Table 2.3). There were no effects of processing corn on DM or starch digestibility. However, DM digestibility was least when dry-rolled corn was fed without WCGF (corn × WCGF interaction, $P = 0.02$). Because WCGF is an excellent source of energy in the form of fermentable fiber, replacing corn with WCGF is a viable and cost effective solution (Blasi et al., 2001).

Experiment 2

Intake of DM tended ($P = 0.09$) to be greater for DRC than for WSC, but DRC increased non-starch intake ($P = 0.02$) (Table 2.4). Corn processing had no effect on starch or ADF intake ($P \geq 0.39$). The increase in DMI for the DRC diets may be due to the diet requiring less mastication because the corn is already cracked, allowing for decreased chewing and thus the ability for more intake. Effects were observed for DMI, non-starch intake, and ADF intake when WCGF was incorporated into the diet. DMI increased when WCGF was added to either WSC or DRC diets ($P = 0.005$) similar to data of Loe et al. (2006). One proposed theory on why DMI is typically increased with the addition of WCGF is its ability to condition the diet and thus make it more palatable (Montgomery et al., 2004). Obviously a palatable diet could entice receiving cattle to return to feed more quickly, improving overall performance, although in Exp. 1 increases in DMI in response to WCGF addition were not observed over the initial 14 d. There was no significant impact of WCGF on starch intake ($P = 0.74$). WCGF increased non-starch intake ($P = 0.001$), and it also increased ADF intake ($P = 0.01$). This could be explained by the low starch content of WCGF, as well as a decrease in the amount of corn fed in the diets containing WCGF. No corn × WCGF interactions were detected for intake ($P \geq 0.14$).

Digestibility of DM, starch, non-starch, and ADF were not impacted by corn processing (all $P \geq 0.16$). This also concurs with the idea that corn does not need to be processed for light weight cattle in order for them to digest the diet as fully as a diet with processed corn. Digestibility of DM was increased with the inclusion of WCGF in the diet ($P = 0.02$). There was a corn × WCGF interaction identified for DM digestibility ($P = 0.02$) due to the DRC diet with WCGF having a 72.3% DM digestibility compared to the DRC with no dietary WCGF inclusion at 62.6% DM digestibility, and WSC diets 68% DM digestibility. Wet corn gluten feed tended to increase starch digestibility ($P = 0.08$), but, starch digestibility for the WSC diets did not differ with WCGF inclusion as much as was observed with the DRC diets (corn × WCGF interaction, $P = 0.09$). Non-starch and ADF digestibilities were increased when WCGF was fed in the diet ($P = 0.03$). Once again, the biggest difference in response to WCGF appeared in the DRC diets (corn × WCGF interaction for non-starch digestion, $P = 0.04$).

Ruminal pH (Table 2.5) was not affected by corn processing ($P = 0.90$). This lack of difference of pH between cattle fed WSC and DRC is perhaps an indication of the thorough mastication occurring in the WSC diets. With the whole corn kernel being effectively damaged by the time it reaches the rumen for fermentation there is no change of pH as compared to DRC. There also was no effect of corn processing on individual VFA or total VFA concentrations (all $P \geq 0.12$). Ruminal liquid passage rate and ruminal liquid volume were not affected by corn processing ($P \geq 0.79$). Ruminal liquid passage rates were greater than typically observed, which may be related to pattern of intake. These heifers were fed once daily and passage rate was measured over a period starting soon after feeding. The lack of steady state conditions might have contributed to an overestimation of the average passage rate that would be experienced over a 24-h period. Our estimates were based on dilution of CoEDTA from 2 to 18 h after feeding, a time period that generated first-order passage kinetics. However, CoEDTA concentrations in the ruminal fluid did not continue to decrease at similar rapid rates between 18 and 24 h after feeding (data not shown).

Dietary WCGF addition tended to increase ruminal pH ($P = 0.09$), which was a response similar to several studies showing either no change or an increase in pH when WCGF replaced steam-flaked corn or dry-rolled corn in finishing diets (Krehbiel et al., 1995; Sindt et al., 2003; Montgomery et al., 2004). This increase in pH would help moderate the rumen environment to help prevent cases of acidosis, as well as keep the rumen in a pH range suitable for optimal fiber digestion. There were also effects of WCGF on many individual VFA (Table 2.5) as well as some WCGF × sampling time effects as shown in Figure 2.1. Acetate concentration (m*M*) was decreased significantly ($P < 0.01$) when WCGF was added to the diet. There was no effect of WCGF on propionate ($P = 0.91$), but butyrate and valerate concentrations were greater ($P \leq 0.05$) for diets with WCGF. Isobutyrate concentration was increased in the 30% WCGF diets, likely due to the fermentation of protein provided by the WCGF, but diets without WCGF yielded greater concentrations of isovalerate ($P = 0.02$). No corn processing effects on ammonia concentration was observed ($P = 0.33$). There was a tendency for lower ammonia concentrations in heifers being fed WCGF ($P = 0.09$). A WCGF × sampling time interaction (Figure 2.1) was observed for valerate and isobutyrate ($P \leq 0.01$); the greatest difference in valerate and isobutyrate concentrations being from 2 to 8 h after feeding. WCGF led to an increase in ruminal concentrations after feeding that were not observed when diets contained no WCGF. Although not significant ($P = 0.08$), a similar pattern was observed for butyrate. The patterns over time for concentrations of acetate and propionate were not greatly impacted by dietary addition of WCGF.

Conclusions

No corn processing effects existed in either Exp. 1 or Exp. 2 for intake or digestibility of DM, starch, or ADF, making it clear that whole corn can be fed to receiving and growing cattle as an energy source. WCGF improved gains, increased intake, increased digestibility, and tended to increase ruminal pH. The addition of WCGF in these receiving and growing diets is a useful way to decrease reliance on corn grain while keeping roughage levels in the diet adequate to ensure overall health in highly-stressed calves.

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Tables

Table 2.1. Composition of diets fed in Exp. 1 and Exp. 2

	Whole-shelled corn		Dry-rolled corn	
	Wet corn gluten feed, %			
Item	0	30	0	30
Ingredient composition, % of DM				
Whole-shelled corn	47.1	28.6	—	—
Dry-rolled corn	—	—	47.1	28.6
Wet corn gluten feed	—	30.0	—	30.0
Alfalfa hay	17.5	17.5	17.5	17.5
Prairie hay	17.5	17.5	17.5	17.5
Molasses	5.0	—	5.0	—
Supplement[a]	12.9	6.4	12.9	6.4
Corn gluten feed	5.2	1.8	5.2	1.8
Soybean meal	2.2	—	2.2	—
Dried distillers grains	1.9	—	1.9	—
Urea	0.85	—	0.85	—
Wheat middlings	0.75	3.1	0.75	3.1
Fat	0.26	—	0.26	—
Salt	0.39	0.38	0.39	0.38
Limestone	0.32	0.82	0.32	0.82
Potassium chloride	0.26	0.02	0.26	0.02
Calcium phosphate, 21% P	0.65	—	0.65	—
Magnesium oxide	0.06	0.01	0.06	0.01
Beef vitamin premix[a]	0.004	0.001	0.004	0.001
Ruminant trace mineral[a]	0.003	0.001	0.003	0.001
Molasses	—	0.19	—	0.19
Rumensin[b]	0.014	0.014	0.014	0.014
Melengestrol acetate[c]	-/+	-/+	-/+	-/+
Composition, analyzed (Exp. 1)				
DM, %	80.6	78.0	81.8	79.3
CP, % of DM	12.5	13.4	12.3	13.2
Starch, % of DM	28.6	21.5	29.3	26.5
Ether extract, % of DM	3.3	2.7	3.1	2.7
ADF, % of DM	20.5	23.8	22.5	24.7
Ca, % of DM	0.63	0.78	0.68	0.67
P, % of DM	0.42	0.43	0.37	0.45

[a]Manufactured by Cargill Animal Nutrition, Minneapolis, MN
[b]Provided 31 mg/kg monensin (Elanco Animal Health, Indianapolis, IN).
[c]Provided 0.5 mg/d (Pfizer Animal Health, New York, NY).

Table 2.2 Effects of whole-shelled corn and dry-rolled corn with and without wet corn gluten feed (WCGF) on gain, intake, efficiency and morbidity (Exp. 1)

	Whole-shelled corn		Dry-rolled corn					
	Wet corn gluten feed, %					*P*-value		
Item	0	30	0	30	SEM	Corn	WCGF	Corn ×WCGF
No. of pens	6	6	6	6				
No. of animals	70	70	69	70				
Days on feed	60	60	60	60				
Initial BW, kg	230.5	230.4	230.5	230.3	1.35			
Final BW, kg	319.1	326.2	320.9	324.3	3.20	0.99	0.03	0.41
DMI, kg/d								
d 0 to 14	5.61	5.69	5.82	5.70	0.10	0.31	0.84	0.35
d 14 to 28	7.38	7.94	7.62	7.42	0.17	0.41	0.29	0.04
d 28 to 60	8.19	8.86	8.25	8.37	0.20	0.31	0.07	0.19
d 0 to 60	7.40	7.90	7.54	7.53	0.15	0.42	0.11	0.10
ADG, kg								
d 0 to 14	1.39	1.65	1.41	1.57	0.16	0.83	0.08	0.66
d 14 to 28	1.60	1.66	1.59	1.80	0.11	0.50	0.16	0.43
d 28 to 60	1.46	1.55	1.51	1.46	0.09	0.68	0.68	0.11
d 0 to 60	1.48	1.60	1.51	1.57	0.05	0.99	0.03	0.42
G:F, kg/kg								
d 0 to 14	0.247	0.289	0.244	0.276	0.029	0.67	0.07	0.79
d 14 to 28	0.218	0.209	0.209	0.242	0.014	0.37	0.35	0.11
d 28 to 60	0.180	0.175	0.184	0.175	0.011	0.78	0.32	0.75
d 0 to 60	0.200	0.202	0.200	0.208	0.008	0.61	0.45	0.66

Table 2.3. Effects of whole-shelled corn and dry-rolled corn with and without wet corn gluten feed (WCGF) on total tract digestibility of DM and starch (Exp. 1)

	Whole-shelled corn		Dry-rolled corn					
	Wet corn gluten feed, %					*P*-value		
Digestibility, %	0	30	0	30	SEM	Corn	WCGF	Corn ×WCGF
DM	59.7	60.2	55.7	61.9	1.15	0.32	0.006	0.02
Starch	68.4	73.4	68.8	71.2	1.35	0.50	0.009	0.33

Table 2.4. Effects of whole-shelled corn and dry-rolled corn with and without wet corn gluten feed (WCGF) on intake and total tract digestibility of DM, starch, and ADF (Exp. 2)

	Whole-shelled corn		Dry-rolled corn					
	Wet corn gluten feed, %					*P*-value		
Item	0	30	0	30	SEM	Corn	WCGF	Corn×WCGF
No. of observations	5	5	5	5				
Diet composition, % DM								
Starch	30.4	28.7	29.1	25.3	1.44	0.14	0.09	0.50
ADF	22.5	22.4	20.8	23.1	0.73	0.47	0.15	0.11
Intake, kg/d								
DM	8.82	9.72	9.18	10.55	0.31	0.09	0.005	0.45
Starch	2.67	2.80	2.66	2.64	0.16	0.59	0.74	0.64
Non-starch	6.15	6.91	6.52	7.91	0.24	0.02	0.001	0.21
ADF	1.98	2.15	1.90	2.43	0.11	0.39	0.01	0.14
Digestibility, %								
DM	68.0	68.0	62.6	72.3	1.85	0.80	0.02	0.02
Starch	78.7	78.8	71.1	79.7	2.27	0.16	0.08	0.09
Non-starch	63.3	63.6	59.1	69.7	2.17	0.67	0.03	0.04
ADF	51.5	54.2	47.5	59.9	3.15	0.78	0.03	0.13

Table 2.5. Effects of whole-shelled corn and dry-rolled corn with and without wet corn gluten feed (WCGF) on ruminal fermentation characteristics (Exp. 2)

	Whole-shelled corn		Dry-rolled corn					
	Wet corn gluten feed, %					*P*-value		
Item	0	30	0	30	SEM[1]	Corn	WCGF	Corn × WCGF
No. of observations	5	5	5	5				
Ruminal								
pH[2]	5.88	5.97	5.87	5.96	0.70	0.90	0.09	0.96
Ammonia[2], m*M*	9.4	7.8	9.8	8.8	1.45	0.33	0.09	0.72
Total VFA[2], m*M*	133.1	125.5	128.5	126.3	4.15	0.55	0.12	0.39
Acetate[2], m*M*	79.9	71.4	77.8	71.7	2.49	0.61	<0.01	0.52
Propionate[2], m*M*	28.8	28.2	27.5	28.4	1.46	0.59	0.91	0.47
Butyrate[2], m*M*	18.7	19.3	17.9	20.0	0.78	0.91	0.05	0.29
Isobutyrate[2], m*M*	1.28	1.54	1.17	1.58	0.09	0.79	<0.01	0.29
Isovalerate[2], m*M*	2.23	2.03	2.12	1.77	0.24	0.12	0.02	0.51
Valerate[2], m*M*	2.15	3.00	1.93	2.88	0.19	0.21	<0.01	0.72
Liquid volume, L[3]	13.4	14.0	12.2	14.1	2.53	0.84	0.66	0.82
Fluid passage rate, %/h[3]	19.7	19.6	18.5	19.8	1.97	0.79	0.76	0.74

[1] Largest value among treatments is reported.
[2] Average of values collected at 0, 2, 4, 6, 8, 12, 18, and 24 h after feeding.
[3] Calculated values from samples collected at 2, 4, 6, 8, 12, and 18 h after feeding.

Figures

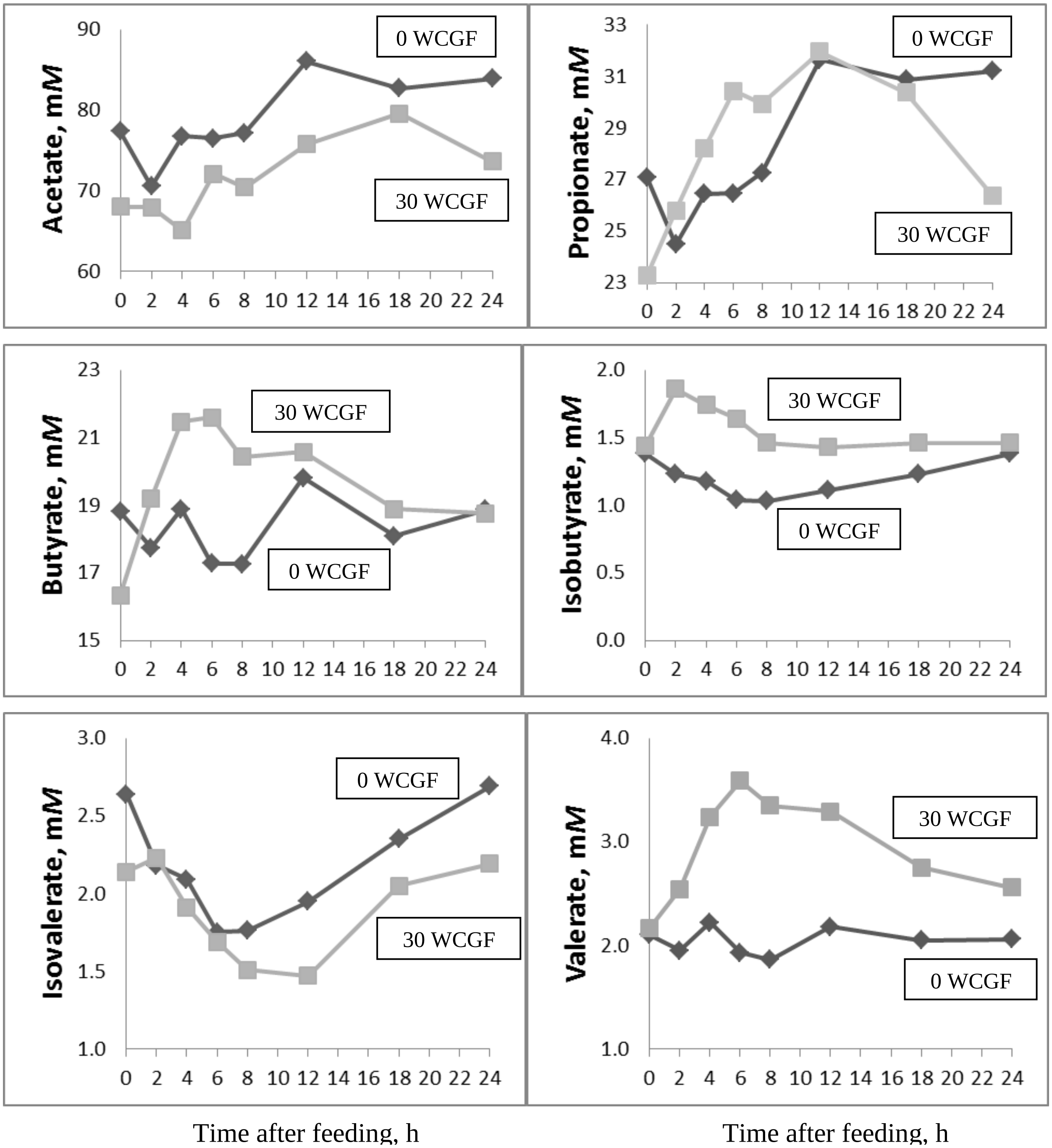

Figure 2.1. Effect of no dietary wet corn gluten feed (0 WCGF) or 30% dietary wet corn gluten feed (30 WCGF) on ruminal concentrations of acetate, propionate, butyrate, isobutyrate, isovalerate, and valerate (Exp. 2). For acetate: WCGF × hour interaction $P = 0.62$; SEM = 3.6. For propionate: WCGF × hour interaction $P = 0.09$; SEM = 1.9. For butyrate: WCGF × hour interaction $P = 0.08$; SEM = 1.1. For isobutyrate: WCGF × hour interaction $P < 0.01$; SEM = 0.11. For isovalerate: WCGF × hour interaction $P = 0.25$; SEM = 0.27. For valerate: WCGF × hour interaction $P < 0.01$; SEM = 0.22.