

MANAGING AND FEEDING HIGH MOISTURE CORN

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— NRAES Field to Feedbank Proceedings, Feb. 1997, pp319-338 —

Introduction

The harvesting, storing, and feeding of high moisture shelled (HMSC) or high moisture ear corn (HMEC) is a popular practice among U.S. beef and dairy producers today. Harvesting corn at a higher moisture content allows for earlier and longer harvests which reduces field losses and allows the use of higher-yielding full-season hybrids. Ensiling high moisture corn as an alternative to artificial drying reduces fuel and labor costs and eliminates costly delays during harvest. Contrarily, harvesting and storing the corn crop as high moisture corn reduces the producers flexibility of marketing the crop since it must be fed to livestock. In addition, spoilage losses can be substantially higher with high moisture corn than dry corn.

Common storage methods used for storing high moisture corn include processing and packing into upright silos, bags or bunkers, or storing the corn whole in oxygen-limiting silos. The storage method of choice will depend on the type and size of the feeding operation. Regardless of the type of storage used, careful management is necessary to insure proper preservation to optimize the feeding value of high moisture corn.

The feeding value of high moisture corn is often a debated amongst nutritionist. Some consider high moisture corn to be equivalent or slightly superior to dry corn while others feel it is inferior to dry corn. In this paper we will discuss the harvest, storage, and feed-out practices involved in producing high quality high moisture corn and review the key factors effecting the

feeding value of high moisture corn for ruminants.

Harvest, Storage And Feedout Management Considerations

Moisture Level

The recommended moisture level for harvesting, storing, and feeding both high moisture shelled and ear corn is between 26-32% kernel moisture. Picked high moisture ear corn will contain approximately 4-6 percentage units higher moisture than high moisture shelled corn when harvested at the same kernel moisture. Basalan et al., (1995) found a very high correlation between the grain dry matter content and the ear dry matter content in corn grown under irrigated conditions (Ear DM = $29.22 + .007125(\text{Grain DM})^2$, $R^2=.996$). The cob, which represents about 12-20% of the dry matter of corn ear, contains approximately one and one half times the moisture content of the kernel. Harvest moisture recommendations are based on the following factors: (1) minimizing field, harvesting, and storage losses (2) providing favorable conditions for fermentation during storage and (3) optimizing the feeding value.

Harvest can typically begin once the corn has reached physiological maturity which is indicated by the formation of a black layer at the tip of the kernel. Black layer is typically achieved at approximately 28-35% kernel moisture depending on hybrid and environmental conditions. Harvesting grain at higher than the recommended moisture contents will reduce dry matter yields and can

lead to extensive fermentation, resulting in increased energy loss during storage. Harvesting below the recommended moisture range also reduces dry matter yields due to increased ear drop and weather damage and makes it more difficult to pack and exclude air. Entrapped air increases the risk of mold growth and/or excessive heating which will lead to increased nutrient loss. Producers should consider adding water during ensiling if the moisture content drops below 25% for shelled corn or below 32% for high moisture ear corn. It is possible to obtain acceptable preservation at moisture contents as low as 21% kernel moisture in oxygen-limiting structures.

Processing

It is critical to eliminate oxygen from the ensiled material as quickly as possible. Processing the grain and packing to exclude the entrapped air is essential for achieving an anaerobic condition in conventional upright silos, bags, trenches, and bunkers. High moisture shelled corn is generally processed at the silo using a hammer mill, tub grinder, roller mill, or a blower with a recutter attachment. Some producers have had success in adjusting the concaves of their combine to substantially crack the grain; however, field losses may be higher unless closely monitored. Processing is not required when storing HMC in oxygen-limiting silos.

High moisture ear can be picked and processed through a tub grinder or a hammer mill prior to ensiling or harvested using a forage harvester equipped with a snapper head. A recutter screen ranging from one-half to one inch should be used to assure that the cob is broken into pieces of one-half inch diameter or less to prevent separation in the silo and sorting by cattle.

New forage harvesters equipped with kernel processors offer an excellent method for processing snapped high moisture ear corn. This process is much more energy efficient and does not reduce the harvester capacity compared to using a recutter screen. It is highly recommended that a silo distributor be used when filling upright silos to prevent separation of cob and grain in the silo. It should be noted that snapped HMEC will contain substantially more trashy material and is harder to pack than processed picked or combined ear corn, thus uniform processing is more critical with this material.

Fermentation

The fermentation process of ensiled high moisture corn is similar to that of silage in that it is an anaerobic (non-oxygen) bacterial fermentation process. However, since high moisture corn contains substantially less moisture than silage, acid production will be limited and the terminal pH will generally be higher than that of silage. The key elements that affect the ensiling process are: (1) oxygen level, (2) fermentable carbohydrate level, (3) moisture content, and (4) the microbial population.

During the initial phase of fermentation, the oxygen remaining in the ensiled mass will be quickly metabolized either by plant cells in the respiration process or by aerobic organisms. Both of these processes are negative in terms of energy loss since they result in the production of carbon dioxide, heat, and water. If the oxygen level is high enough, excessive heating will occur, resulting in increased energy losses and heat damaged protein. Another negative effect of entrapped oxygen is that it supports the growth of the undesirable spoilage organisms. If yeast and mold growth is high during the initial ensiling period then the material will likely have poor aerobic stability during feedout. Respiratory losses can generally be controlled to less than 1-2% but depend on the producer's ability to fill the silo rapidly and eliminate oxygen from the mass.

Once anaerobic conditions are established, the anaerobic bacteria begin to grow and ferment the water soluble carbohydrates (sugars) to lactic acid, acetic acid, and ethanol which drops the pH of the ensiled mass. The primary bacterial population involved in this process are the lactic acid bacteria. These organisms are classified as either heterofermentative or homofermentative depending on their ability to convert sugars to lactic acid. (McDonald et al., 1991). Heterofermentative organisms are less effective than the homofermentative organisms in that their fermentation results in the production of one mole of carbon dioxide, one mole of acetic acid or ethanol, and one mole of lactic acid from the fermentation of one mole of glucose or fructose while the homofermentative organisms produce two moles of lactic acid with no production of carbon dioxide. Lactic acid is the preferred fermentation acid since it will drop the pH faster than acetic acid. Likewise, ethanol has no preservative capabilities in silage or high

moisture grains. Under ideal conditions the fermentation will be completed within seven days. However, if the ambient temperature is low (less than 60 degrees F) and/or the microbial population on the crop is low or of poor quality, the fermentation may take up to 21 days.

Once the pH has dropped to around 4.5 the microbial activity slows or ceases and the ensiled mass will remain stable as long as anaerobic conditions are maintained. Covering the ensiled mass in bunkers or trenches with plastic and sealing with tires or other weights is highly recommended. Oxygen will penetrate the exposed surfaces, resulting in significant top spoilage losses otherwise. Some producers spray the top of the silo down with water prior to applying the plastic to assure a good seal.

The amount and type of organic acids produced during the fermentation is dependent on the level of fermentable substrate, the moisture level of the crop and the quantity and quality of the microbial population. In general, most lactic acid bacteria only ferment simple sugars in the crop and do not have the enzyme systems to utilize the complex carbohydrates such as starch (McDonald et. al., 1991). The normal sugar level in HM shelled corn will only be around 2% since most of the sugar is converted to starch during the maturation process. The sugar content of HM ear corn will generally be around 3-4% but drops as the corn matures. Thus, material that is more mature will generally have a lower level of fermentable sugars and will not ferment as well. Likewise, the higher the moisture content the greater the extent of the fermentation. Water is a vital part of the fermentation process as it is essential for achieving a good pack and excluding oxygen. It is also the medium that brings the fermentable carbohydrates and the microorganisms together and distributes the acid throughout the ensiled mass. Fermentation losses are generally going to be between 1-2% and are largely dependent on the quantity and quality of the bacterial population.

Feedout

Perhaps the most critical management consideration facing producers storing and feeding HMC is the feedout process. Feedout losses can account for up to 50% of the total DM loss in HMC. Aerobically spoiled HMC can also have a dramatic impact on animal

performance. Once the HMC is exposed to oxygen during feedout, aerobic microorganisms will once again begin to grow and metabolize nutrients in the grain. Yeast usually begin to grow first since they can tolerate the lower pH. Yeast growth can usually be detected by an ethanol odor in the HMC. Some strains of yeast have the ability to utilize lactic acid as a substrate and will metabolize the lactic acid under aerobic conditions. This causes the pH to rise, which then allows the acid sensitive fungi to grow. Generally, the first sign of aerobic spoilage is heating. Once the material has started to heat, mold growth is generally forthcoming. In order to minimize aerobic losses during feedout it is essential that the producer remove a minimum of 2-4 inches of material off the face of the non-oxygen limiting silos each day during cool weather and as much as 6-10 inches during warm weather. This should be a primary consideration when designing a silo for storing HM corn. Losses from aerobic deterioration can be significant (up to 5%) if the silo is not managed properly and the material is prone to spoilage (i.e. high pH, high yeast and mold counts, and slow feedout). Table 1 summarizes the potential loss during storage and feedout of HM corn. With proper management total storage and feedout losses can generally be kept to less than 3 %. However, if poorly managed and ambient temperatures are high, losses can approach 10% resulting in substantial nutritional and economic loss. Losses are usually 2-4 % units higher for HMEC compared to HMSC since it is more difficult to exclude air from this product.

Additives

The primary purpose of using an additive on HMC is to aid in the preservation of the ensiled material by improving the fermentation or extending the aerobic stability. Additives used today can be broadly categorized as either acids, enzymes, or inoculants. There is considerable variation among products within each category being sold today and producers should not consider all products equally effective. Additives should not be viewed as a replacement for proper management but instead as a part of proper management. Research in our laboratory shows that microbial inoculants developed specifically for high moisture corn are more effective in reducing dry matter loss, improving aerobic stability, and improving feeding value than those developed

for use on silage. Additives are reviewed extensively in other reports within these proceedings.

High Moisture Corn Feeding Value

Nutrient Composition

Table 2 shows the approximate nutrient composition of the different forms of high moisture corn vs dry corn. Actual nutrient composition will vary with growing conditions, hybrid, and harvest practice. High moisture shelled corn (HMSC) will have a protein and

Beef Cattle

Merrill (1971) reported in an extensive review of the literature that ensiling high moisture corn was an effective method of handling and feeding corn to beef cattle. He concluded that high moisture corn produced more efficient gains (+5 to 10%) compared to same grains in the air dried form. In a review and summarization of 21 comparisons of dry versus high moisture grain, Clark (1975) reported that feedlot cattle fed HMC were 6.1% more efficient than those fed dry corn. Corah (1976) reported in a review of 44 trial comparisons that the feeding value of high moisture corn was slightly superior to dry rolled corn when the HM corn was stored in either an oxygen limiting silo or acid treated but was slightly inferior when fed as ground ensiled high moisture corn. In a more recent review Owens (1994) reported that finishing beef cattle fed high concentrate (>80%) rations containing high moisture shelled corn (HMSC) will generally consume less feed DM, have similar daily gains and have slightly better feed conversions compared to those fed dry rolled corn. In general, the reported trial data suggest that high moisture shelled corn gives equal to or slightly superior performance to dry rolled corn. However, performances varied with the type and degree of processing, corn moisture level, and ration formulation which will be discussed in a later section of this paper.

Most research trials comparing ensiled ground HM ear corn (HMEC) to dry ground ear corn show that HMEC gives essentially equal average daily gain but increases feed efficiency by about 10% (Merrill, 1971, Corah, 1976). Nearly, all of these trials were conducted with picked corn having moisture contents ranging from 30-40% moisture. Some other comparisons involving HMEC harvested near the extreme limits of high

energy content similar to dry shelled corn while high moisture ear corn (HMEC) contains substantially more fiber and will have a lower protein and energy value compared to shelled corn. Snapped corn which contains husk and ear node, in addition to the cob, will have a higher fiber level, and lower protein and energy value than picked ear corn. Combined ear corn will usually retain from 20 to 80% of the cob and varies with the combine setting. The nutrient composition of combined ear corn will generally be superior to picked ear corn.

or low moisture, or when inadequate feeding management was involved gave lesser results. Few trials exist evaluating the feeding value of snapped high moisture ear corn. It is logical to assume that the feeding value of this product will be inferior to picked or combined HMEC and will largely depend on the amount of trash (husk, ear node, and tassel) which is included during harvest.

Oklahoma researchers (Van Koevering, et al. 1994) evaluated the feeding value of ground combined high moisture ear corn (GE) compared to ground (GS) or rolled shelled (RS) high moisture corn in finishing beef cattle diets containing 9% pelleted alfalfa hay as the roughage source. Dry matter intake for steers receiving GE and RS were 9.5 and 6% higher, respectively, than for steers receiving GS. Grain intake for steer fed GE was 14.1 and 20.8% lower than steers receiving GS or RS, respectively, due to the presence of the cob in GE at approximately 20% of the diet dry matter. Efficiency of feed conversion was 13.2% and 10.3% greater for steers receiving GS and RS than steers fed GE. However, gain per unit of corn was 7.5% greater with GE diets than GS and 10.8% greater for GE than RS. Calculated net energy for gain was 14.3 and 11.0% greater for GS and RS than GE. The researchers concluded that the cob has only about 23% as much net energy for gain as does grain. In a subsequent feeding trial conducted at this same station by Hill et. al, (1995) ground combined HMEC was fed with no added roughage or with 8% ground alfalfa hay, performance of steers was essentially equal for both HMEC diets compared to those fed ground HMSC with 8% added alfalfa hay. This trial suggests that available energy of the corn cob in high moisture ear corn (corn and cob meal) was equal to grain.

Dairy Cattle

In a summary of 11 lactation studies Clark (1976) reported that mean yield of milk for cows fed ensiled shelled corn was identical to the yield of milk for cows fed dry corn. However, cows fed dry shelled corn produced 3.7% more milk than cows fed acid treated corn. Feeding ensiled high moisture shelled corn resulted in a 3.9% higher milk yield compared to feeding acid treated high moisture corn but resulted in 2.6% lower milk yield compared to feeding ensiled high moisture ear corn. Milk yield was 1.4% higher for ensiled high moisture ear corn compared to dry shelled corn. Merrill (1971) concluded that experimental results with ensiled high moisture shelled corn or high moisture ear corn show that either form is essentially equal in feeding value of dry corn. He suggested that there is no substantial evidence that there is any major or consistent differential effects of HMEC vs. dry corn ear corn, HMSC vs dry shelled corn, or HMEC vs. HMSC on production response or feed efficiency for lactating dairy cows. In a more recent study, Dhiman and Satter (1994) reported that cows fed diets containing either dry rolled corn or HMEC or ground HMEC had similar feed intakes but trended higher for HMEC and GHMEC. Milk yield (3.5% FCM) was slightly higher with HMEC and GHMEC than with dry rolled corn. Milk composition was not effected by corn type. Feed efficiency was slightly improved with HMEC and GHMEC over dry rolled corn.

It appears that lactating dairy cows can effectively utilize the cob fraction in HMEC. While it has been suspected that the digestibility of the cob in HMEC is higher than that of the cob in dry ear corn it is not logical to assume that this difference would result in HMEC having a similar metabolizable energy to shelled corn. The unexpected performance with HMEC is more likely related to improved rumen function, palatability or reduced metabolic disorders. It should be noted that the HMEC used in these trials was harvested with a traditional corn picker or modified combine. It is generally recognized that snapped ear corn containing the husk and varying amounts of trash will have a lower feeding value than picked corn.

Factors Which Affect The Feeding Value of HMC

Moisture Level

Many nutritionists have observed that the feeding value of HMC is often variable. Intakes are often less than predicted particularly with corn ensiled at moisture levels above 30%. Owens and Thornton (1976) concluded from a review of 36 published beef feeding trials that for every 1% added moisture above 24%, dry matter intake decreased by about 1% when HMC was compared to dry rolled corn as the sole source of grain in the diet (Figure 1). They also concluded that metabolizable energy content of HMC increases with moisture content. On average, energy value of HMC equaled dry corn at 23% moisture and increased by .3% for every 1% higher moisture.

While moisture level in high moisture corn is highly correlated with its voluntary dry matter intake it is not the moisture per se that is responsible for the observed intake depression. Moisture level is the driving factor in the extent of the fermentation process and is related to the rate of starch digestion of the grain itself. To test the influence of moisture content on the site of digestion in vivo, Aguirre et al. (1984) reconstituted dry ground corn to 15, 20, 25, 30, and 35% moisture and ensiled the material. The resulting corns were fed to 5 cannulated steers in a 5 by 5 latin square experiment. Site of starch digestion results are shown graphically in figure 2. As moisture level increased, starch digestibility in the rumen and total tract increased linearly. Starch digestion in the small intestine also increased as moisture level increased. Recent research in our laboratory utilizing an Automated In Vitro system adapted from Scholfield and Pell (1995) likewise clearly demonstrates that ground high moisture corn ensiled at 29% moisture has a much faster rate and extent of digestion than ground high moisture corn with 23% moisture (Figure 3). We have also found that HM corn ensiled at higher moisture levels will have a lower pH and higher soluble nitrogen level than HM corn ensiled at lower moisture levels.

(Figures 4 and 5.). These effects are directly related to the microbial fermentation. Our data suggest that inoculation with lactic acid bacteria increased the rate and extent of digestion of low moisture corn and is associated with lower pH and higher levels of soluble nitrogen.

Because of the structure of its starch granule, corn is not as extensively degraded in the rumen as wheat or barley (McAllister et al. 1993). It is postulated that the acidification breaks down some of the protein matrix surround the starch in ensiled high moisture corn freeing up more starch granules to microbial digestion in the rumen. Increased soluble nitrogen in silage has often been view as a negative attribute, however, in high moisture corn it may actually be related to improved starch digestion and improved metabolizable energy. Fellner et al., (1993) reported that inoculating HMEC (28% moisture) with the same inoculant used in our studies significantly ($P < .05$) increased average daily gain and improved feed efficiency when fed to finishing steers.

Soluble Nitrogen

Much of the debate over the feeding value of HMC has centered around the fact that much of the protein in HMC is solublized during ensiling. Sprague (1976) was among the first to suggest that soluble nitrogen content in HMC was related to poor performance in cattle. Soluble N is highly correlated with moisture level in high moisture corn and increases during the length of storage (Thornton 1976, Stock et al., 1991, Prigge 1976). This relationship would suggest that the observed depressed intakes with high moisture corn might be related to poor rumen N utilization and an overload of ammonia in the rumen. Correlation coefficients between the chemical indices in ensiled HMC is shown in Table 3. Soluble nitrogen continues to increase during extended storage past the time when fermentation is thought to be complete and pH has stabilized (Thornton 1976, Stock et al., 1991). It is postulated that the increase in soluble N is due to acid hydrolysis over time of the protein.

Processing

Ekinci and Broderick (1995) reported that grinding high moisture ear corn (68% DM) which was rolled prior to ensiling through a 3/8 in. screen improved milk yield 2.4 kg/d when fed in diets containing 53% alfalfa silage, 42% HMEC and 5% supplement. Cows fed the ground HMEC diet also had significantly greater yields of fat, protein, lactose, and SNF than cows fed the rolled HMEC. Grinding of the HMEC increased DM and starch digestibility and significantly ($P < .01$) decreased ruminal ammonia concentration. The authors concluded

To test the hypothesis that soluble N in HMC is poorly utilized or contributes to an overload of rumen ammonia, Prigge (1976) fed steers diets containing 80% dry corn or HMC (30% moisture) supplemented with either soybean meal or urea in a metabolism study. Post feeding ruminal pH depression was greater for steers fed HMC vs. dry corn indicating greater ruminal starch digestion. But contrary to common belief, rumen ammonia concentration were actually lower for the steers fed the HMC vs dry corn regardless of supplement source (Figure 6). Nitrogen retention as a % of N absorbed was significantly ($P < .05$) higher for the steers fed HMC. These data suggest that ammonia released from the soluble N in the HMC was used more extensively for microbial protein synthesis. These data were future substantiated by the work of Aguirre et al. (1984) described earlier who found that microbial protein yield increased with increasing corn moisture.

Owens et al., (1994) reviewed 15 feedlot performance trials which evaluated the effect of various protein supplements on the intake and performance of cattle fed HMC diets. (Table 4.) Averaged across trials, it appears that supplementation with SBM slightly increased feed intake and rate and efficiency of gain over urea supplement alone. In contrast, urea on average proved superior to cottonseed meal alone or cottonseed plus urea supplementation.

In one study there was an interaction between protein source and moisture content of the HMC (Gill et al., 1982). With the wetter grain, urea appeared superior to intact protein whereas with the drier HMC intact protein had the advantage. These data would suggest that supplementing HMC with a protein source with a similar rate of degradation will increase rumen microbial efficiency.

that greater ruminal fermentation with the ground HMEC diet, compared to the non ground diet, increased ammonia utilization and microbial protein synthesis by rumen microbes.

Processing has been shown to have a large impact on the feeding value of feed grains by reducing particle size and thus altering the rate, site and extent of starch digestion (Galyean et al., 1981). In general, grinding high moisture corn increases the rate and extent of ruminal starch digestion of high moisture corn compared to rolling the HMC. However, under some

circumstances it is suggested that grinding may actually increase starch flow to the small intestine (Allen, 1994). It is important to note that grinding increases both the rate of digestion and the rate of passage which have counteractive effects on ruminal digestibility. Therefore, fine grinding may have less effect on ruminal starch digestibility for animals with high levels of intake, such as dairy cattle in early lactation, than for growing or fattening animals, dry cows or dairy cattle in late lactation (Allen, 1994). Owens (1994) reviewed the effect of type of processing on the performance of finishing beef cattle in trials where high moisture corn was fed as the sole grain source. He separated the data into three different moisture ranges (18-22, 23-26, >27%) within each processing form (whole, rolled, ground). This data (table 5) suggest that average daily gain and feed efficiency for rolled high moisture corn increased with moisture level above 26%. However, with ground HMC, average daily gain was lower when the corn moisture was above 26%. This interaction suggest that the cattle fed the ground HMC having moisture levels exceeding 27% were most likely experiencing subclinical acidosis. However, Secrist et al. (1995) reported that finishing beef steers fed tub ground HMC (30% moisture) had similar feed intake and ADG as those fed rolled HMC (30% moisture) and that ground corn improved feed efficiency (4.46 vs. 4.60 lb DM/lb gain). Ground alfalfa hay was fed as the roughage source in this trial.

Site and Rate of Starch Digestion

It has been clearly demonstrated that the rate and site of starch digestion of HMC is highly correlated with moisture content (Aguirre et al, 1984b, Stock et al., 1991, Owens et al., 1994) whether the moisture is endogenous or added at the time of ensiling. Since moisture addition increased starch digestion in the rumen as well as the small intestine, the factor limiting digestion is probably the same at both sites. In cattle, this factor is probably size or accessibility of particle encasing the starch (Owens, 1994).

In theory, digestion of starch in the small intestine is energetically favorable (Owens et al., 1986); however, experimental data have not been able to establish positive relationships between small intestinal starch digestion and glucose absorption (Kreikemeier et al., 1991). Efficiency of post-ruminal starch digestion and absorption of glucose decreases with increasing

starch passage to the small intestine (Nocek and Tamminga, 1991). Kreikemeier et al. (1991) infused corn starch in the abomasum of steers and recorded disappearances from 86 to 55% as the amount of starch infused increased from 480 to 1,440 g per day. These studies suggest a lack of adequate pancreatic amylase activity as the primary reason that there is not 100% digestion of starch in the small intestine (Huntington, 1994). Kreikemeier et al. (1991) also found that only about 30% of the starch disappearing in the steer's small intestine resulted in net portal glucose absorption and suggest that other routes of disappearance are microbial fermentation to VFA and small intestinal metabolism of glucose to lactate. The less efficient digestion of starch in the small intestine with increasing starch appearance suggest that some starch not fermented in the rumen may escape digestion altogether, decreasing total tract digestibility and energy availability (Theurer, 1986).

Ration Formulation Considerations

Increasing ruminal starch digestion to maximize total tract availability and microbial yield must be balanced against the negative effects of acid accumulation in the rumen (Allen, 1994). For this reason many cattle feeders tend to feed alfalfa hay instead of silage with high moisture corn to stimulate saliva production and increase ruminal buffering capacity. Mader et al., (1991) evaluated three different roughage sources; alfalfa hay, alfalfa haylage, and corn silage in steer finishing diets containing ground high moisture corn (27% moisture) as the energy source. He found that the DM intake of steers fed alfalfa hay or alfalfa silage as the roughage source were 7.9 to 8.8% greater than intakes of steers fed corn silage as the roughage source which supports the concept that alfalfa does increase rumen buffering. However, rates of gain and feed efficiency were poorer for steers fed alfalfa hay or alfalfa silage than those fed corn silage as the roughage source. Davis (1980) also reported greater gains and lower feed:gain ratios for steers fed corn silage compared to those fed alfalfa hay as the roughage source in high moisture corn diets. These data would suggest that feeding roughage sources which are comparable in ruminal degradation rate to the grain source may be preferable to feeding roughage sources with vastly different degradation rates than the grain source. Roughage level and particle size

are also important considerations when feeding diets containing high moisture corn and should be adjusted to provide adequate effective NDF to maintain maximal energy intake (Allen, 1994). Increasing particle size of the roughage may allow the inclusion of more starch or more rapidly available starch sources in the diet increasing energy availability and microbial protein production. Stock et al., (1991) reported that feeding a combination of dry grain with ground HMC having a moisture level greater than 28% increased dry matter intake, average daily gain, and feed efficiency compared to feeding HMC as the sole grain source. It is postulated that the positive associative response in these trials was due to reducing subclinical acidosis since the total tract starch digestion was higher with 100% HMC diets than for the 67:33 HMC and dry rolled sorghum diet.

Summary

The harvesting, storing, and feeding of high moisture shelled (HMSC) or high moisture ear corn (HMEC) is a popular practice among U.S. beef and dairy producers today. Harvesting corn at a higher moisture content allows for earlier and longer harvests which reduce field losses and allows the use of higher-yielding full-season hybrids. Ensiling high moisture corn as an alternative to artificial drying reduces fuel and labor costs and eliminates costly delays during harvest. High moisture ear corn appears to offer an attractive opportunity to feeders that grow their own crops. Harvesting the cob increases field yields up to 15-20% and the feeding value appears to be better than expected. New forage harvesters equipped with kernel processors should facilitate this operation and make it more attractive to producers.

Regardless of the type of storage used, careful management is necessary to insure proper preservation of high moisture corn. The ideal harvest moisture appears to be between 27-30% kernel moisture. Processing is necessary when storing high moisture corn in non-oxygen limiting structures to aid in compaction and eliminate entrapped oxygen. Covering bunker silo is highly recommended to prevent oxygen penetration. It must be noted that high moisture corn is a perishable product once exposed to oxygen; therefore, feedout rates, silo design and bunk management are important

consideration when feeding these products. Inoculation with a research proven bacterial inoculant is recommended to aid in the fermentation process, improve aerobic stability and increase the feeding value.

Feeding trials have demonstrated that properly managed high moisture corn (>27% kernel moisture) has a feeding value equal to, or slightly superior to, that of dry corn when fed on an equal dry matter basis. However, the feeding value of HMC can be quite variable and is influenced by several factors including; moisture content, processing, fermentation and diet formulation. On balance, it would seem that the variation in the feeding value of HMC is likely associated more with the rate and extent of ruminal starch digestion than any other factor. When performance has been less than expected, intakes are generally lower than that for dry grain, indicating subacute ruminal acidosis may be implicated. The feeder must understand the impact of the factors which effect ruminal starch digestion rate in order to optimize the feeding value of high moisture corn. High moisture corn with a kernel moisture content below 25% should be processed finer while high moisture corn with a moisture content above 30% should be coarsely processed. Diets should be formulated to provide protein and roughage sources which are similar in degradation rate as the HMC source. In order to maintain rumen pH at an acceptable level and avoid metabolic disorders effective fiber level may need to be adjusted upward when feeding ground HMC with moisture levels exceeding 27%.

In the future, the development of analytical technologies like the Automated In Vitro System (AIVS), Near Infrared Spectrophotometry (NIRS) and Near Infrared Transmittance (NIT) to quickly access the rate and extent of digestibility as well as the nutrient content of feedstuffs will help nutritionist fine tune rations to optimize performance. Until that technology is available common sense and empirical knowledge on how to feed high moisture corn will make the difference between success and failure when harvesting, storing and feeding high moisture corn.

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Tables

Source of Loss	% DM Loss
Respiratory (oxidative)	1-2
Fermentation	1-2
Aerobic Spoilage (top spoilage. Feedout losses)	0-5
Total	2-9%

	Snapped Ear Corn	Picked Ear Corn	Shelled Corn
Corn, %	72-78	80-84	100
Cob, %	16-19	16-20	--
Husk, %	6-8	--	--
Crude Protein, %	8.8	9.2	10.0
Crude Fiber, %	11.5	8.5	2.3
NE(m), Mcal/lb	.92	.98	1.04
NE(g), Mcal/lb	.54	.58	.67
Mader, et al., 1983			

Table 3: Correlation Coefficients Between Characteristics of Ensiled Corn (Thornton, 1976)

	D.M.	pH	Lactic Acid	Acetic Acid	Soluble		Pepsin Insol N	IVDMD	
					N	NPN		21 HR	48 HR
pH	.65**	--	--	--	--	--	--	--	--
Lactic Acid	-.69**	-.87**	--	--	--	--	--	--	--
Acetic Acid	-.42*	-.11	.32	--	--	--	--	--	--
Soluble N	-.81**	-.80**	.71**	.21	--	--	--	--	--
Soluble NPN	-.79**	-.74**	.67**	.29	.98**	--	--	--	--
Pepsin Insol N	.32	.36*	-.29	-.07	-.61**	-.57**	--	--	--
IVDMD, 21 HR	-.62**	-.31	.34	.40*	.35	.36*	-.07	--	--
IVDMD, 48 HR	-.18	-.03	.18	.20	-.15	-.15	.18	.37*	--
Particle Size	.44*	.52**	-.49**	-.09	-.38*	-.38*	-.01	-.51*	-.43*

Table 4: Effect of Protein Source on Feeding Value of HMC in Feedlot Rations^a

Protein Source	ADG (lb/d)	DMI (lb/d)	F/G
SBM	3.06	19.98	6.72
Urea	2.95	19.70	6.85
% Diff	3.50	1.37	-2.01
CSM	3.08	19.67	6.41
Urea	3.14	19.80	6.34
% Diff	-1.92	-0.65	1.22
CSM or SBM + Urea	2.80	17.93	6.44
Urea	2.73	17.23	6.35
% Diff	2.66	3.86	1.13

^a Owens (1994) Summary of 15 trials from OSU, KSU, or Univ. of NE

Table 5: Effect of Moisture Content and Processing on Feeding Value of HMC for Finishing Feedlot Cattle (Owens, 1994)

Moisture	Content	Whole	Rolled	Ground
18-22%	DMI, lb/d	19.68	19.5	18.9
	ADG, lb/d	2.95	2.77	2.69
	Feed/gain	6.79	7.3	7.10
23-26%	DMI, lb/d		18.7	19.4
	ADG, lb/d	--	2.75	2.7
	Feed/gain	--	6.91	7.29
>27%	DMI, lb/d	--	17.1	17.3
	ADG, lb/d	--	2.97	2.59
	Feed/gain	--	5.86	6.77

Figures

Figure 1: Correlation Between Moisture Content of High Moisture Corn and Dry Matter Intake in Feedlot Cattle (Owens, 1976)

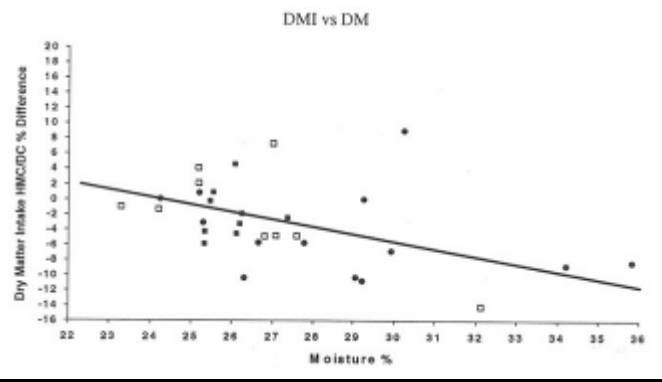


Figure 2: Starch Diegestion of HMC Harvested at Different Moisture Levels (Aguirre et al., 1984)

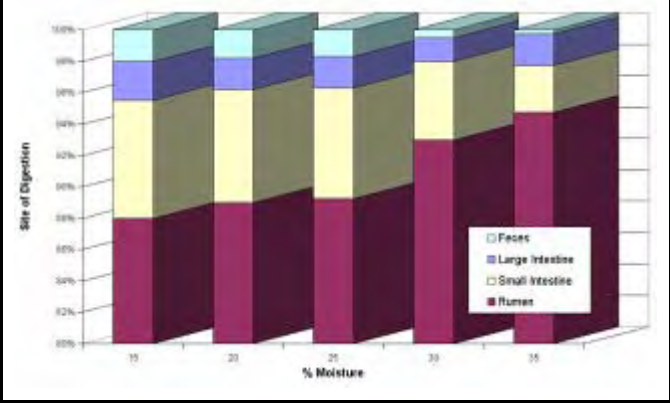


Figure 3. In vitro Rate and Extent of Digestion of High Moisture Corn Harvested at Two Moisture Levels With or Without Pioneer 1189 High Moisture Corn Inoculant

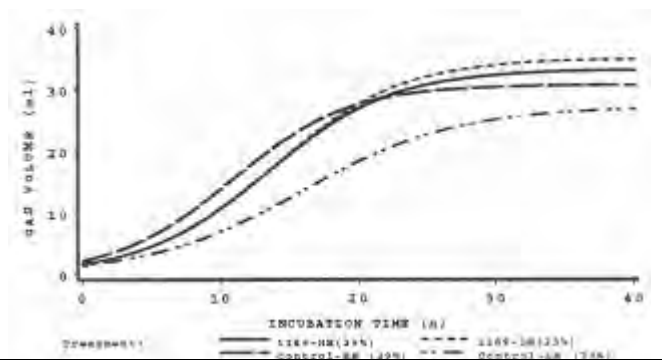


Figure 4. Relationship of Moisture Level and Soluble N of Inoculated and Untreated HMC

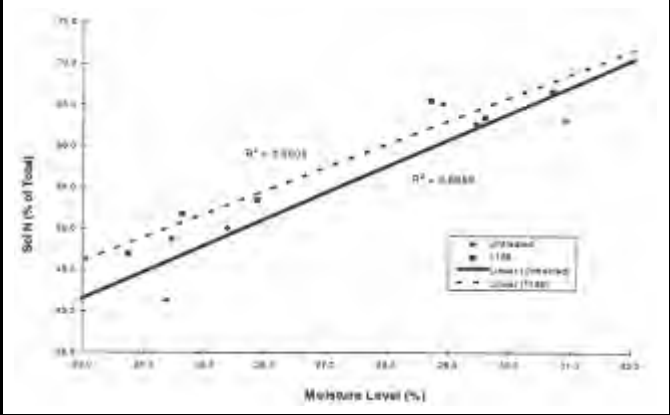


Figure 5: Relationship of Moisture Level and PH of Inoculated and Untreated HMC

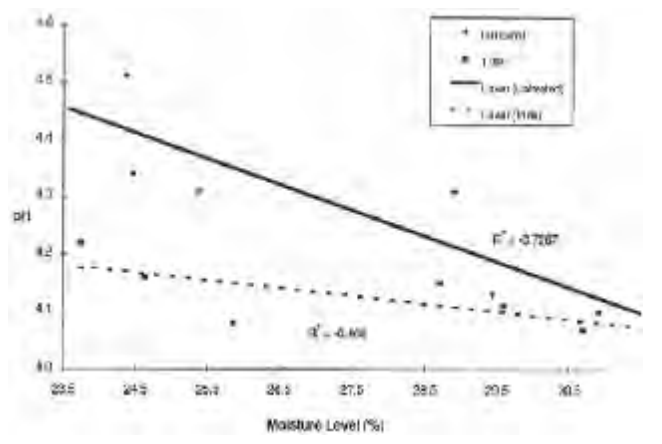


Figure 6: Rumen Ammonia Levels of Steers Fed Various Rations (Prigge, 1976)

