Don Gill

Proceedings

High Moisture Grains Symposium

Oklahoma State University

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HIGH MOISTURE GRAINS SYMPOSIUM

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INTRODUCTION

In July 1976, a group of animal scientists met at Oklahoma State University to discuss and plan methods for improving the utilization of high moisture grains. Most of the research personnel across the U.S. and Canada who have worked with high moisture feeds were in attendance. This group of scientists and industry leaders assembled on their own initiative to share their research findings and ideas because of a widely felt need to improve the utilization of high moisture feeds.

It became apparent at the symposium that greater uniformity in reporting future data is essential to help scientists interpret research. Suggestions prepared by Drs. Owens, Goodrich, Buchanan Smith, and Thornton are included on the next pages. It is hoped that as many of these suggestions as possible will be included in subsequent reports.

We at Oklahoma State University wish to thank all who spoke and attended the symposium for their most important part in contributing to the success of the meeting.

Don Gill

Fred Owens

Don Wagner

STANDARD PROCEDURES FOR HIGH MOISTURE CORN ANALYSIS

It is recommended that dry matter, total nitrogen, soluble nitrogen and particle size be included in all future HMC research.

1. General: If possible, analyses should be performed on wet (non-dried) unground samples.

   Grinding of samples should be performed when frozen with dry ice or liquid nitrogen.

2. Dry matter: In order of preference -

   a. Absolute water determination (Hood, Allen, Goodrich and Meiske, 1971. J. Anim. Sci. 33:1310).

   b. Toluene distillation (Dewer and McDonald. 1961. J. Sci. Food Agr. 12:790).

   c. Lyophilization

   d. Oven drying (AOAC)

3. Soluble nitrogen quoted as percent of total N: In order of preference -

   a. Buffer solution (Wohlt, Sniffen and Hoover. 1973. J. Dairy Sci. 56:1056), or phosphate buffer.

   b. 0.1 N HCl solution (Brady. 1960. J. Sci Fd. Ag. 11:276).

   c. Ethanol solution (Sprague and Breniman. 1969. Feedstuffs 41:46:20).

4. Particle size: In order of preference -

   a. Standard seives, quoting geometric mean particle size and standard deviation (Ensor, Olson and Colenbrander. 1970. J. Dairy Sci. 53:689).
   (Second d_i in definitions is meant to be $\bar{d}_i$).

   b. Modulus of fineness (ASAE R2461, ASAE Yearbook 1967, p. 301)

5. Rumen fluid in vitro digestion should have nitrogen supplemented.

   Other procedures are detailed in "Silage Fermentation by A. J. G. Barnett, 1954, and Forage Fiber Analyses, 1970, U.S.D.A. Agriculture Handbook No. 379.

Signed: F. N. Owens
R. D. Goodrich
J. G. Buchanan-Smith
J. H. Thornton

STORAGE AND USE OF HIGH-MOISTURE GRAINS

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An advertisement by A. O. Smith Harvestore Products, Inc., Arlington Heights, IL, asks, "Why dry grain when you can go directly from field to storage?"

The question could have been, "Why take the water out of fresh harvested high-moisture grain and then after storing for a period of time give it to a steer and ask him to put the water back into the grain so he can digest it?"

Drying grain increases cost and may not be necessary unless the grain is going into market channels. If drying is not necessary, then how does one store high-moisture grain? How useful is it as a livestock feed after storage? What are the pitfalls to be avoided? And what is needed to improve the usefulness of the technique?

As I understand it, these questions are what this conference is about. I do not propose to give a complete answer to any one of these questions, but I will attempt to make a meaningful contribution.

In the Midwest there has been a steady trend over the past 20 years toward earlier harvest of corn with an accompanying increase in the amount of corn that is field shelled. Field shelling amounted to only 4 to 5 percent in 1958, but had increased to over 1/4 in Iowa and over 1/2 in both Illinois and Indiana by 1968 and at present amounts to over 3/4 of the acreage harvested for grain. Earlier harvesting and field shelling produce a kernel high in moisture that is unsuitable for storage in the usual manner because ambient temperature and humidity are still relatively high at that time of year. This environment combined with high-moisture grain is ideal for mold growth. Although most molds are harmless, several produce toxic materials and all molds tend to lower grain quality and usefulness. Molds propagate from spores which can be found everywhere. When temperature and moisture conditions are right, grain will deteriorate in proportion to the amount and duration of the mold infestation. Drying fresh harvested high-moisture shelled grain to less than 15 percent moisture creates an environment unfavorable to mold growth. Similar results can be accomplished by lowering temperature, but this is a continuing and relatively expensive process compared to drying. The molds with which we are concerned generally require, in addition to proper temperature and humidity, a favorable acidity range. Acidity levels are modified by placing the grain in a silo with sufficient moisture to permit the grain to go through the ensiling process. Chemicals have recently become available for direct application to high-moisture grain for preservation. Ensiling as a means of preservation has been available for a long time and is suitable for high-moisture ground ear corn as well as high-moisture shelled grain. Tests at the Iowa and Indiana stations in 1956 and 1957 with cattle showed ensiled high-moisture ground ear corn (30 to 36% moisture) to be 9 to 15 percent superior to air-dried ground ear corn (Burroughs, et al, 1971). Storing high-moisture ground ear corn requires 2 1/2 to 3 times as much storage volume as shelled corn (U.S.D.A. publication ARS 22-56, 1960). The increased cost for storage volume, the additional power required for grinding ear corn and the readily available equipment for field shelling virtually eliminate from consideration the harvesting and storing of high-moisture ear corn.

Following the favorable results of the early studies at Iowa and Indiana with ear corn, high-moisture shelled corn was tested in Iowa and found to be about 5 percent inferior to rolled air dried shelled dry corn. An Indiana test showed a 2 percent advantage and four Illinois tests showed a 5.25 percent disadvantage. However, it was observed in the Iowa tests that approximately 20 percent of the high-moisture shelled corn grain, which was fed in the whole form, was unmasticated and passed through the cattle apparently undigested. When corrections were calculated to account for the undigested grain, the high-moisture shelled grain showed an 8 percent advantage over dried grain and led to the realization that shelled high-moisture whole kernels should be processed prior to feeding to cattle (Burroughs, et al, 1971).

The percentage of moisture in the grain and the amount of roughage in the ration may have a bearing on the value of high-moisture grain for livestock. Burroughs, et al (1971) summarized as follows:

Improved feeding value of high-moisture corn over dry corn.

Moisture content of ground ear corn	
23 through 32 percent (four trials)	7%
33 through 44 percent (four trials)	13%
Moisture content of whole shelled corn	
23 through 27 percent (five trials)	7%
28 through 35 percent (four trials)	5%
Roughage content of ration	
Less than 15 percent (two trials)	none
15 to 35 percent (five trials)	6%
More than 35 percent (three trials)	4%

The above data show an advantage for high-moisture corn stored in the ear form. Although this may be true, my observations at the Iowa Station are that a ration for feedlot cattle composed of ground ear corn and supplement does not always allow the full genetic potential for daily gain to be expressed. Thus, in spite of the superior performance of ensiled high-moisture ear corn compared to dry ear corn, it may be inferior to processed high-moisture shelled corn under certain circumstances.

When the proceedings of this symposium are summarized and recommendations made, I suggest that tests to determine the relative values of shelled and whole ear corn rations, including the availability and cost of supplemental roughage for the shelled corn ration be considered. A similar and closely related matter is the high-moisture grain that is stored and fed as a segment of corn silage. Does grain stored and then fed in that form deserve or require more scientific inquiry? It does represent a significant proportion of the nutrient makeup of silage.

Ensiling High Moisture Corn Grain

Hoffman and Self (1975) studied the effect of season (summer and winter) and type of storage system (drying - D, oxygen-limiting - OL and concrete stave - CS) on the feeding value of high-moisture corn grain over a 4-year period involving eight trials (four in summer and four in winter) with yearling steers. Each of the four harvest seasons provided grain for both the subsequent winter test and a test the following summer.

The data in table 1 indicate that cattle on the summer tests gained faster than those on the winter tests, which is no surprise to Midwest feeders and is not significantly related to or affected by the grain used in the ration. There was, however, an observation not reported in the original manuscript that I want to relate here. Although not statistically significant, steers receiving grain from the OL system gained slower in every summer test than did steers fed grain from the other two systems. During the summer tests each system contained only the grain that was left from the previous harvest, thus in the OL system the major portion of the storage volume was empty of grain in summer.

In table 1 there was an effect of year and an effect of system of storage (both are significant at the .10 level). The daily grain DM intake over all eight trials was 14.15 pounds for D, which is 5.13 percent greater than the 13.46 pounds for OL and 4.12 percent greater than the 13.59 pounds for CS. Daily gains over the eight trials averaged 2.66 pounds for D, 2.57 for OL and 2.68 for CS. The grain DM intake data and the rate of gain data results in DM conversion rates of 5.32, 5.24 and 5.07 for D, OL and CS, respectively, based on post-storage sampling. It is of particular importance to note that these ratios are based on post-storage sampling with dry matter determinations made with a forced-draft oven. The oven process removes a portion of the volatile materials other than water which are credited as water. This tends to bias the data by underestimating the percent dry matter in ensiled grain.

Table 1. Four-Year Summary -- Effect of Season and System for Storing Corn Grain on the Performance of Yearling Steers.

Season	Storage system	Starting weight	Days on test	ADG[a]	DM/hd/day[b,c]
Winter	D	647	174	2.31	13.11
	OL	627	178	2.35	12.80
	CS	629	178	2.38	12.98
Summer	D	691	109	3.01	15.20
	OL	693	101	2.79	14.12
	CS	693	92	2.99	14.21

[a] Effect of year significant ($P < .10$; effect of season significant ($P < .001$).
[b] DM intake based on post-storage samples dried in forced-draft oven.
[c] Effect of year significant ($P < .05$); season significant ($P < .001$; type of storage significant ($P < .10$).

High moisture grain stored in a concrete stave (unsealed type) probably undergoes a higher degree of fermentation, producing a higher level of volatile acids than does grain in an oxygen-limiting system. If that is the case, and if the drying of post-storage samples does bias downward the dry matter content of ensiled grain, the efficiency at which grain from a concrete stave is converted would be biased to the positive side. In order to eliminate bias from this and other sources such as drying and handling losses, our study was designed to determine storage system efficiency on the basis of the ratio of the total dry matter in fresh grain going into a system to beef liveweight gains produced when the grain from that system was fed to steers. All other ingredients of the ration were held constant so that grain was the only variable. This approach permits all facets and peculiarities of each system such as handling and fermentation losses to accumulate and be reflected in the liveweight gains produced. Our report also included data on the grain dry matter removed from each system after storage. From these pre- and post-storage values, coupled with liveweight gains of steers, the DM requirements per unit of liveweight gain could be determined for each storage system on both a pre- and post-storage basis (table 2).

Table 2. Comparison of Storage Systems -- Units of Grain Required per Unit Liveweight Gain by Yearling Steers.

	D	OL	CS
Fresh harvested corn grain[a]	7.9	7.6	8.0
DM in fresh harvested corn grain[b]	5.86	5.64	5.94
DM in ensiled corn grain[c]	--	5.24	5.19

[a]Grain corrected to 25.8 percent moisture for all systems.
[b]Ratio of units of grain DM entering storage to units of liveweight produced when fed to yearlings.
[c]Ratio of units of DM in post-storage sampled corn grain to units of liveweight produced when fed to yearlings.

On the basis of fresh harvested grain the CS system was 1.27 percent less efficient than the D system, whereas the OL system was 3.8 percent more efficient than the D system and 5.0 percent more efficient than the CS system. Using the DM conversion ratios in table 2, each bushel of fresh harvested grain going into a system for storage should produce 8.08, 8.39 or 7.97 pounds of liveweight gain when stored in the D, OL and CS systems, respectively. If the D system is used as a base, there is 0.11 pound less liveweight gain produced per bushel of corn when processed through a CS system (8.08 vs. 7.97) and .31 pound more gain per bushel when processed through the OL system (8.08 vs. 8.39). An estimate of the relative economic worth of grain for feeding can be obtained by assuming a specific economic value for liveweight. For example let us assume liveweight is valued at 40 cents per pound. A bushel of fresh harvested grain processed through the OL system produced 8.39 pounds of gain, which at 40 cents per pound is worth 12.8 cents per bushel more for yearling feedlot cattle than is a bushel of dried corn. A bushel processed through the CS system produces .11 pound less beef which at 40 cents per pound of gain is worth 4.4 cents per bushel less than dried grain. This results in an overall advantage for the OL system of 17.2 cents per bushel in feeding value over the CS system. It is important to recognize that the above calculated values relate only to pre-storage fresh grain feeding values, and do not include any calculations for investment, taxes, overhead, labor and so forth. Such factors may vary considerably among feedlot operators.

Calculations on the post-storage dry matter conversion ratios in table 2 indicate that the dry matter in one bushel of grain after being ensiled in an OL system will produce 9.03 pounds of gain compared to 9.12 pounds for the CS system. At 40 cents per pound of gain a bushel of corn from the OL system would be worth $3.61 and from the CS system would be worth $3.65. This advantage of 4 cents per bushel for the CS system plus the 17.2 cent advantage for the OL system results in a 21.2 Cent per bushel spread in the calculated values of a bushel of corn for feeding yearling cattle. At a market value of

$2.50 per bushel, 21.2 cents represents 8.5 percent of the value of a bushel of grain. Thus it is quite clear that much of the data reported on the basis of post-storage sampling and analysis contained an error which biased the data to favor the grain ensiled in an open system such as the tower silo or the trench silo. The first step in correcting such an error is to recognize that an error exists when the feeding value of grain is determined on the basis of post-storage sampling. Secondly, some adjustment factor should be applied to dry matter values from post-storage samples in order to better reflect its true value for feeding.

Using the difference between pre-storage and post-storage dry matter values to compare systems directly, our data showed grain DM losses during storage of 6.0 and 12.5 percent for the OL and CS systems respectively (table 3). It should be kept in mind that all dry matter values were determined with an oven. This procedure tends to bias the percent dry matter content of ensiled grain from some sources downward due to the loss of volatile fatty acids during the dry matter determination. Such a bias could result in the system which produces the highest level of volatile acids appearing to be the most efficient when in fact it is not. In all probability this pehnomenon has tended to rate the concrete stave and the trench higher in storage efficiency for high-moisture grain than they deserve.

Table 3. High-Moisture Corn Grain Dry Matter Losses When Ensiled.

System	Moisture %[a]	Dry matter		
		Pre-storage	Post-storage	% loss
OL	25.8	171,521	161,256	6.0[b]
CS	26.1	174,843	152,966	12.5

[a] Weighted mean based on pooled weight and moisture content of individual loads of grain as harvested and as assigned to a high-moisture storage system.
[b] System effect significantly different ($P < .10$).

In some years the western one-third of Iowa is marginal in plant available moisture for corn production and suffers corn grain yield reductions due to drought an average of 2 of every 5 years. Over a 17-year period at the Northwest Iowa Research Center at Sutherland, selected sorghums have produced slightly higher grain yields than adapted corn varieties. Sorghum stalks stand more erect and are higher in moisture and crude protein than corn stalks immediately post-harvest, making the crop residue more suitable than corn for grazing or for harvest as silage. Artificial drying of sorghum grain has not been favored because of the small kernel size and the accompanying equipment modifications required. Storing sorghum grain in the high moisture form by-passes the need for drying and enhances the opportunity to use sorghum as an alternate crop to corn when drought, disease or insects pose a problem for corn producers. The early harvest of sorghum grain in the high moisture form also will leave the crop residue in a more usable form than when the grain is left on the stalk in the field for drying.

Ensiling High-Moisture Sorghum Grain

Ware, et al (1976) reported a 3-year study on the production, storage and feeding of sorghum grain to yearling steers at the Allee Research Center in the same facilities used for the previously discussed 4-year high-moisture corn study. The grain was stored in the whole kernel form and then rolled just prior to feeding once daily. As with the earlier corn grain studies, after the cattle had reached "full feed," the daily silage and supplement levels were held constant while the daily grain intake was allowed to vary according to appetite on a per-lot basis. Each harvest provided grain for two tests, one during the following winter and one the following summer. Winter tests were terminated when 80 percent of the steers were judged to grade U.S.D.A. choice and the summer tests were terminated when the grain supply within a storage system was exhausted.

The results in table 4 of this 3-year study (six trials) of storage systems for sorghum grain indicate that the grain storage system has little influence on the average daily gain of yearling cattle receiving the grain. Grain dry matter conversion to liveweight gain was most efficient when the high-moisture grain sorghum was stored in an oxygen-limiting silo, regardless of whether pre- or post-storage dry matter values were used. A slight advantage existed for the concrete stave system over the artificially dried system when post-storage dry matter values were used. This could be a reflection of the inherent bias when dry matter of ensiled grain is determined with a drying oven. Dry matter losses during storage (difference between pre- and post-storage DM) of the sorghum grain were significantly greater in the concrete stave system (8.50%) than in either the oxygen-limiting system (6.12%) or the artificially dried system (6.52%).

Table 4. Three-Year summary: Sorghum Grain Dry Matter and Efficiency of Gains by Yearling Steers.

System	Percent moisture		Grain DM consumption/ day (lb)	Average daily gain (lb)	Grain DM/lb liveweight gain		% dry matter loss in storage
	Pre-storage	Post-storage			Post-storage	Pre-storage	
CS[a]	24.73	22.70	16.26[b]	2.64	6.17	6.74	8.50[b]
OL	24.09	24.54	15.80[b]	2.60	6.07	6.47	6.12[c]
D	20.65	13.42	17.15[c]	2.71	6.32	6.76	6.52[c]

[a] CS = concrete stave silo; OL = oxygen-limiting silo; D = dry in conventional bins.

[b,c] Means differ $P < .01$.

Chemical Preservation of High-Moisture Corn Grain

Starting in the winter of 1971-72 and through the summer of 1974, six trials were conducted to determine the usefulness of chemicals in preserving high-moisture corn grain. Propionic acid (PA) at either 0.5 or 0.9 percent by weight and ammonium isobutyrate (AIB) at 1.33, 1.50 or 1.66 percent by weight were the chemicals used for treatment. Following treatment and thorough mixing the high-moisture grain was stored in either wood or metal bins until removed for feeding to yearling steers in either fence line bunks or self-feeders. Parameters evaluated were: average daily gain (ADG), grain dry matter consumption on a daily basis (GDMC), grain dry matter per unit of liveweight gain (DM/G), dry matter loss during storage (DML) and system efficienty (SE). In the first year a comparison between wood and metal bins indicated no significant difference between them and therefore was not included in future tests. Over the six trials PA-treated grain did not differ from dried grain in ADG, GDMC or DM/G, but was superior for DML and SE ($P < .001$ and .05, respectively). In a 2-year comparison steers fed AIB-treated grain did not differ from those receiving dried grain in ADG or GDMC, but were superior for DM/G, DML and SE ($P < .05$, .001 and .01, respectively). A 1-year test in which AIB and PA were compared directly with each other and with dried grain indicated no differences between AIB and PA in steer performance for DML and SE, but the pooled mean of AIB and PA lots was superior to dried grain fed to steers.

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Systems for Storing and Handling High Moisture Corn

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Interest in harvesting and storing grain at a high moisture content is increasing due to increases in costs of artificially drying. A careful analysis of research results suggests that the effects of feeding high moisture corn rather than dry on performnace are small (Goodrich, Dexheimer and Meiske, 1974). Thus the benefits of an earlier and longer harvest period to reduce field losses, to allow the use of full season hybrids to facilitate fall plowing, and cost savings due to reduced handling and not have to dry the grain determine the value of a high moisture corn system. However. proper high moisture storage improves the feeding value of sorghum grain (Riggs and McGinty, 1970).

Careful management is necessary to insure preservation of high moisture grain. A number of systems can be used to store and feed high moisture grain. The reasons for using various systems are primarily related to their relative advantages and disadvantages in individual operations. The purpose of this paper is to discuss management procedures that must be followed in the use of each system, and the relative advantages and disadvantages of each under various conditions.

Components of Systems for Storing and Handling High Moisture Grain

Regardless of storage structures used, the following practices must be followed to insure preservation and to obtain a high quality feed and to handle high moisture grain.

Exclusion of air: In order to successfully preserve any high moisture feed without freezing or chemical addition to acidify it, the forage or grain must ferment in an environment that is free of air as possible. Preservation is then achieved by the formation of organic acids during fermentation by anaerobic bacteria as soon as plant cell respiration ceases (Watson and Nash, 1960). The pH of ensiled grain drops to 4.5-5.5 (Goodrich, Byers and Meiske, 1975). This prevents the growth of undesirable organisms whose end products cause reduced palatability, nutrient loss or toxicity; the most notorious of these are the aflotoxins (Oldfield, 1973). The method used to exclude air varies with the storage method used, but usually includes some combination of grain moisture content and processing before storage, packing to exclude air internally and sealing the silo to prevent spoilage at exposed surfaces. Various minimum rates of feeding are necessary to prevent spoilage at the exposed surface, requiring silo sizes to be comparible with the amount to be removed daily, based on the number of cattle fed and ration used.

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[1] Presented at the Symposium on Methods of Improving the Utilization of High Moisture Grains for Cattle, July 22 and 23, 1976, Stillwater, Oklahoma

Grain Moisture Content: Excessive fermentation occurs at a high corn moisture content, resulting in increased energy loss during storage (Goodrich, Byers and Meiske, 1975) and increased protein breakdown (Dexheimer, 1973). Dry matter intake also decreases (Goodrich, Dexheimer and Meiske, 1974) If the moisture content is too low, exclusion of air becomes more difficult and mold growth and excessive heating can occur, resulting in energy losses and heat damaged protein. An acceptable range in grain moisture content is 25 to 30%, with an upper limit of 33% (Geasler, 1971; Maddex, 1972; Paine, 1976). This is a logical operating range, as harvesting and handling of the grain becomes easier below 30% moisture, but field losses will increase as the season progresses, due to increased field losses as the grain becomes drier and risk of wind, snow and stalk rot causing ear droppage and down stalks increases. To avoid these problems, it is desirable to start harvesting high moisture corn at about 30% moisture and be finished before the corn is less than 25% moisture.

When these recommendations for grain moisture content are followed, ear corn will be 28 to 32% moisture content, with 25 to 40% moisture of the ensiled ground ear corn being acceptable limits (Maddex, 1972).

Better utilization of sorghum grain is obtained when it is stored whole at 28 to 32% moisture, and then rolled before feeding (Baker, 1973).

It is possible to obtain acceptable preservation at moisture contents as low as 21% moisture in oxygen limiting structures (Goodrich, Byers and Meiske, 1975). However, carmelization due to excessive heating has been reported at a moisture content of about 24% (Perry, 1976). Thus to be safe, the moisture content should be within the ranges discussed.

Need for Processing: Much data suggests that high moisture corn must be ground or rolled before feeding (Baker, 1973). However, when this data is separated by level of roughage fed, it appears that high moisture corn need not be ground or rolled if fed in a ration containing less than 15% forage (Dexheimer, 1973). Other research indicates high moisture sorghum grain should be stored whole and rolled before feeding (Baker, 1973). However, various degrees of processing are used to allow compaction as a means of excluding air, unless an oxygen limiting structure is used as mentioned previously. Most grinding into storage is done at the silo, using a hammer mill, burr mill, or a blower with a recutter attachment (Maddex, 1972). Field grinding of ear corn can be done with a mill behind gathering rolls or by the cylinder of a corn combine. To minimize fines, a roller mill can be used to process corn into tower silos that are reasonably tight; it is also used to process whole high moisture corn out of storage.

Handling, Metering, Measuring and Mixing: High moisture grain is more difficult to handle than forage or dry grain, and it bridges easily. These factors must be taken into account when selecting equipment to handle it. In tower silos, unloaders used for silage can be used for high moisture corn. A 6 to 10 cubic foot V-bottom bin with a small auger and variable speed motor is a good method for metering ground high moisture corn, and a minimum of 15 to 20 feet of auger will mix high moisture corn with silage (Maddex, 1972). Supplement can be added through a metering device to an auger that conveys the silage and grain to get a limited mix of the total ration. A more thorough mix of grain and supplement can be obtained by using a stationary horizontal mixer,electric mix mill or PTO grinder-mixer. Those using bunker or pit silos should use a truck or wagon mounted mixer to blend high moisture grain, supplement and forage. The grain and supplement should be added to the mixer before the forage to obtain the best distribution of ingredients in the ration.

Selecting and Managing Various Storage Systems for High Moisture Grain

A number of factors need to be considered when selecting a storage system, including size of feeding operation, uniformity of grain usage throughout the year, desire to re-fill the structure with reconstituted grain at times other than at harvest, labor requirements and cost of the structure. The merits and special management needed for oxygen limiting tower, conventional tower and horizontal silos will be discussed here.

Oxygen limiting tower: There are several makes of these available, and are commonly known. The major advantages of this type of structure are as follows:

1. The grain can be stored whole. This eliminates the need for processing at harvest time. Some studies indicate that high moistute grain is utilized more efficiently if stored whole and processed before feeding than if ground into storage, especially sorghum (Baker, 1973). Also corn will need no processing if fed in high concentrate rations (Dexheimer, 1973). Thus this system allows the grain to be processed in the way it will be most efficiently utilized by the cattle.

2. A wider range in moisture content can be allowed. This allows a longer harvest period or filling with grain from several sources without having to add water.

3. Less storage losses when smaller quantities are stored. Dry matter losses are expected to be 2 to 5% lower in oxygen limiting than in conventional tower silos, and 5 to 10% lower than when stored in horizontal silos (Midwest Plan service, 1976). This advantage diminishes as the size of silo increases, however. Losses as low as 1 to 2% have been recorded in large horozintal silos (Paine, 1976).

4. Flexibility in rate of feeding. Many farmer-feeder operations will vary the rate of grain feeding, depending on the amount and types of crops grown that are available at various times of the year and variations in number of cattle fed. In structures that are not oxygen limiting, minimum amounts of the grain on the surface must be removed daily to prevent spoilage.

Conventional Tower: Many cattle feeders use conventional rather than oxygen limiting tower silos for the following reasons.

1. To utilize tower silos formerly used for silage. Many feeders built horizontal silos for silage when they expanded, making existing tower silos available for high moisture grain.

2. More storage can be obtained for the same total investment. Due to the seasonal nature of grain harvest, a farmer must find storage for all of his grain at harvest. When capital is limited, he likely will choose a conventional tower silo to store high moisture grain if several structures are needed to store the grain he wishes to feed but his volume is not large enough or his feeding rate is too variable to use a horizontal silo. Also having several storage structures rather than one allows him to utilize some of the silos to store, and feed simultaneously, several other crops when they become emptied. Also in some years he may not harvest and store as much high moisture grain, and part of the storage structures can be used for other feeds.

Conventional tower silos must be in good condition and doors must fit tightly to prevent air from leaking into the silo. It may be advisable to either calk the door joints or to cover the doors with a strip of plastic film. Reinforce by adding additional bands according to manufacturers recommendations. If the moisture content is within the limits mentioned previously, the grain can be stored without grinding or rolling if the silo is tight. Most blowers will partially crack the grain enough to facilitate packing under many conditions. If the storage conditions are questionable, however, the grain should be rolled or ground prior to storage to exclude air. A minimum of 2 inches in cold weather and 3 to 4 inches in warm weather should be removed daily to prevent spoilage (Geasler, 1971; Maddex, 1972).

Table 1 gives the number of cattle needed to remove 2 inches/day at various levels of grain feeding. The values in this table are also estimates of the number of cattle that can be fed each day for 360 days on a 60 foot depth in silos with various diameters and with various levels of grain feeding to estimate the size and number of silos needed.

Table 1. Number of cattle required to feed 2 inches/day from various sizes of tower silos

	Silo Diameter (Feet)			
	16	20	24	30
Lb. fed/head daily[1]	----Number of Cattle Required---------			
5	267	419	604	944
10	133	209	302	472
15	89	140	201	315
20	67	105	151	236
25	53	84	121	189

[1] 28% moisture basis, and 40 lb./cubic ft.

This is an average for the silo. More will be removed at the bottom than at the top/foot of depth.

Horizontal Silos: As cattle feeding operations expand, the need to increase the size of feed storage units and the speed at which they can be filled and at which feed can be removed from them also increases. In recent years a number of cattle feeders have successfully stored high moisture grain in horizontal silos (Geasler, 1970; Paine, 1976), with dry matter losses as low as 2 to 3% (Paine, 1976; Gill, 1976). It is obvious that the cost of storage is lowest with this type of structure. This system is most adaptable to operations feeding over 500 head, considering the optimal width and depth and amount that must be removed from the surface to prevent spoilage (Geasler, 1971; Paine, 1976). Also the slower rate of removing feed from a tower silo becomes more of a problem in larger feedlots, but is not as much of a problem in smaller lots.

A detailed description of the various types, proper location and construction of these silos is beyond the scope of this paper. An excellent description of the location, construction, equipment and filling has been prepared by Paine (1976). However, a brief description of proper management for minimizing spoilage will be discussed here.

1. The size of silo should be based on rate of removal necessary to prevent spoilage, ease of sealing, and ease of movement of trucks and feeding equipment. For example, a 38 foot width allows use of a 50 foot plastic cover, resulting in about 5 feet of overlap on each side for sealing (Paine, 1976). The pile of grain should be at least 12 feet high and not over 18 feet high to minimize surface exposed but not so high as to make packing and removal of feed dangerous and difficult (Paine, 1976). At least 4 inches/day should be removed from the surface to prevent spoilage (Geasler, 1971; Paine, 1976; Midwest Plan Service, 1976). Thus the width should be based on the number of cattle on feed and the lb./head/day fed, and the length on the number fed/year and the level of grain feeding. It may be desirable to have more than one silo if the amount fed daily varies and to allow continued feeding when the next year's harvest begins. Table 2 gives estimates of the number of cattle required to remove 4 inches/day at an average depth of 14 feet with various width and levels of grain feeding. This table also indicates the number of cattle that can be fed for 360 days from 120 feed of length to estimate the length of silo needed.

Table 2. Number of cattle required to feed 4 inches/day from various widths of horizontal silos

	Silo Width (Feet)					
	30	40	50	60	70	80
Lb. fed/head daily [1]	Number of Cattle Required					
5	1400	1867	2333	2800	3267	3733
10	700	933	1167	1400	1633	1867
15	467	622	778	933	1089	1244
20	350	467	583	700	817	933
25	280	373	467	560	653	747

[1] 28% moisture basis, and 50 lb./cubic foot.

2. The grain must be processed prior to ensiling; a hammermill or roller mill is commonly used for this purpose. The particle size, however should be no smaller than necessary for adequate packing.

3. The moisture content should be kept within the range of 25 to 30%. Make provision for adding water if the grain becomes dry. A simple, effective,

inexpensive method for accomplishing this is described by Paine (1976).

4. Minimize surface exposure during filling. Fill one end to full depth quickly. Compact thoroughly during filling. A large wheel tractor with a blade or a crawler tractor is used for piling, leveling and packing. Crown the grain in the center and slope to the top of the outside walls to allow drainage. Smooth the grain with a long handled trowel at the end of each day. When filled the grain should be uniformly smoothed down to the top of the side wall. Then avoid walking on the grain. After crowning and smoothing, place a layer of corn silage about 6 inches thick over the top of the grain, then cover with new 6 mil black plastic. Be sure the plastic is wide enough to leave enough overlap (2 to 5 feet on each side) so that the edge can be sealed with dirt or gravel. Then completely cover the surface of the plactic with old automobile tires, so that each tire is covering the other tires around it. Each days grinding should be crowned, smoothed and sealed at the end of each day or the following morning. Chopped forage can be placed over the plastic rather than tires.

5. Four to 6 inches should be removed/day to avoid spoilage on the surface. Remove the grain uniformly without disturbing the portion not being fed that day. This is accomplished by scraping the grain from the face of the silo. A commercial unloader that scrapes the material from the face of the silo and augers it into a truck or feed wagon works best. A front end loader tractor can also be used, but more care must be taken to not loosen too much of the surface. If the number of cattle is not adequate to utilize a 4 inch slice from the entire surface, divide the silo by feeding from only a portion of the face. Remove only as much of the plastic cover as necessary as removal of the grain progresses.

Where drainage permits, pit silos where concrete is poured on the preshaped earthen embankment are the most desirable for ease and safety of filling and ease with which it can be sealed. Tilt up panels may work satisfactorily if the joints are tight and the walls are reinforced well enough to withstand the pressure of the high moisture grain. Check with the manufacturer before using this type for high moisture grain. Also be sure to provide for some method of sealing at the outside edges.

Re-Constitution

Water is often added to dry grain so that it can be ensiled to permit the use of the same storage facility and feeding system throughout the year, to preserve grain that is going out of condition in dry storage, or to improve the efficiency of utilization by the cattle. This is an especially useful method to improve the utilization of the starch and protein in milo. One gallon of water/10 bu. of grain is required to raise the moisture content 1%. The water should be mixed with the grain or forage immediately after it is ground and as it is being added to the silo. This can be accomplished by placing several spray nozzles that are controlled by valves over a slightly inclined auger (Paine, 1976).

Chemical treatment. Commercial preservatives that contain nearly 100% propionic acid will effectively preserve high moisture grain. The amount used depends on the moisture content and length of storage. This method is useful when it is desirable to store high moisture grain whole in temporary storage, such as on a cement slab or in wooden bins or coated nets. The chemical is usually sprayed on the grain under flow and pressure controls. Exposed metal must be coated, including nails in wooden bins. The cost is similar to drying, and the expected performance appears to be similar to that with dry grain. Manufacturers recommendations should be carefully followed as to rates of application and safety procedures to follow while using.

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Effects of Prestorage Processing on Feeding Value of High Moisture Corn*

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High moisture corn research was started in Nebraska at our Northeast Station in 1969. An oxygen-limiting silo was converted for these trials by adding a top unloader for ground high moisture corn storage. In the first attempt too few cattle were fed to prevent mold and spoilage of the ground high moisture corn ahead of feeding. Consequently, the trial was rescheduled with double the number of cattle. The test compared dry rolled (DR)--15% moisture, oxygen-limiting silo rolled (OLSR)--24% moisture, ground medium moisture (GMM)--24% moisture, and ground high moisture (GHM) corn--27% moisture, with alfalfa hay supplying about 10% roughage dry matter. Wet corn (18% moisture) was fed to two extra lots. Results were unfavorable to the ground high moisture corn and favorable to the extra lots where whole wet corn was fed.

The second test (1970) compared roughage levels of 1 1/2 and 3 lb dry matter from corn silage (66.5% moisture) with DR--13%, OLSR--19%, and GMM--18.5%. Feeding the higher level of roughage improved results; however, two bunker silos were built for storing ground high moisture corn since heating occurred just ahead of feeding in the upright silos even with the faster rate of feeding.

The first trial using bunkers (1971) was essentially the same in design as the 1969-70 trial. Comparisons included DR--14%, OLSR--24%, GMM--29%, and GHM--35% corn. In addition, one lot of cattle was fed OLS corn in whole form (OLSW). Alfalfa hay was fed to provide 7 1/2% roughage dry matter.

Acid-treated corn was added to our studies in 1972. Also, OLSW was added as a routine treatment. Moisture content of the grains were OLS--23%, acid treated (A)--24%, GMM--25%, and GHM--29%. Corn silage was used for roughage at 10% of the ration dry matter. A second test using the same grains included a dry whole shelled corn (DW) and 7 1/2% alfalfa haylage as the roughage.

After two years using the bunker (with little or no heating ahead of feeding), results were not greatly improved over corn stored in upright silos. We returned to the upright silo with GMM--26% for more detailed study, and also we examined the use of bentonite and ground limestone as additives. (In a "cleanup" study in 1972, bentonite and limestone appeared to improve gain to a greater extent than sodium bicarbonate.) Because OLSW corn had performed well in spite of considerable molding near the end of summer tests, the bunkers were used to store whole corn in a mix of either alfalfa haylage or ground corn (to fill air spaces). A new smaller oxygen-limiting bin (OLB) was purchased for oxygen-limiting storage. The roughage fed in 1973 was alfalfa haylage at 10% of the ration dry matter. The 1973 results were favorable for storing whole corn in bunker silos in spite of some mold development which resulted from inadequate pack combined

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with a rather low moisture content. The treatments were DR--15%, OLBR & W--22%, ground medium moisture--26% (control, limestone and bentonite), 30 GMM-70 whole--22.5% (control and limestone), 90 whole – 10 alfalfa haylage--25% (control and limestone).

Corn silage mixed with whole corn for storage and ground snapped corn (GSC) were added for the 1974 study. Alfalfa haylage was stored with or fed at 10% of the ration except where corn silage was stored with whole grain (82 whole – 10 corn silage), and in the GSC cobs and shucks provided the roughage.

Drought scuttled the planned 1975 test. Then in 1976 mixtures of 70 whole and 30 ground were compared at two moisture levels, 21% and 25%. Corn silage was fed at the rate of 12% of the ration dry matter to provide roughage in these tests.

Now to more detail in regard to the results:

(1) High moisture corn ground before storage (GMM and GHM)--This product stored in either upright or bunker silos has produced consistently lower rate and efficiency of gain compared to dry corn in high concentrate finishing rations (Table 1). Rate and efficiency of gain were 9 and 8% less, respectively, in the six comparisons made over the 4-year period. Moisture level does not appear to influence rate of gain appreciably (Table 2). Efficiency of gain was slightly superior for the higher moisture levels where direct comparisons could be made in our study, with one exception. Increasing the roughage level in one test minimized the disadvantage for ground high moisture corn in the one comparison we made (Table 3). Adding ground limestone or bentonite at feeding time did not appear to improve performance (Table 8) even though in one preliminary trial ground limestone, bentonite, and sodium bicarbonate all appeared to have a beneficial effect on rate of gain.

In these studies we have not uncovered practices which make high moisture corn stored ground equal to dry corn. Ground corn stored in upright silos heated before feeding, but the differences were about the same for ground high moisture corn from bunker silos that had a minimal heating problem. Although higher moisture levels in our tests appeared to be slightly superior (particularly in efficiency of gain), tests were not designed to determine the most effective moisture level. From our data it would appear, however, that ground high moisture corn can be stored at a moisture content ranging from 18.5% to 35% without apparent spoilage. The feeding trials we conducted at the Northeast Station do not encourage the use of ground limestone at high levels or bentonite. Our rations when these were fed, however, were dry enough that both bentonite and ground limestone tended to settle to the bottom of the bunk. We wonder if the results would have been the same had separation been prevented. Increasing roughage, in our one test, appeared to minimize the disadvantage of ground high moisture corn, but did not entirely eliminate the problem.

In our tests the ration has been fed once daily. Contrary to popular belief, dry matter intake did not appear to be depressed appreciably by feeding high moisture grain. In isolated instances, high moisture grain did appear to reduce intake, but the averages are not appreciably different. A very slight reduction did occur for ground high moisture corn compared to ground medium moisture corn.

(2) High moisture corn stored in oxygen-limiting silos or bins--High moisture corn stored whole in an 8,000 oxygen-limiting silo was rolled daily before feeding in early tests. Performance of cattle fed this product were essentially the same as for dry rolled corn (Table 4). However, some molding occurred before the trials were terminated. In two of the three years, molding appeared to inhibit appetite somewhat near the end of the trial. As a result, a smaller oxygen-limiting grain bin was substituted.

Preliminary studies of feeding whole high moisture corn were made in 1970 and 1971. Those results encouraged us to feed whole high moisture corn. Now we use it as a control. Rate and efficiency of gain have been improved in every test except 1973, resulting in 3% to 5% improvement in rate and efficiency of gain (Table 5).

(3) Storing whole shelled corn in bunker silos--The desirable performance from feeding whole high moisture corn encouraged us to try systems for storing whole high moisture corn in bunker silos. Mixtures of WHM and wilted 4th cutting alfalfa or alfalfa haylage have been equal in feeding value to corn stored in oxygen-limiting bins and fed with alfalfa haylage (Table 7). In the first poor packing resulted in some mold in the alfalfa haylage.

Mixing high moisture whole shelled corn with corn silage also resulted in satisfactory storage and performance (Table 7).

A third method of storing whole high moisture corn in bunkers was mixing about 30% ground high moisture corn with the shelled corn. The first year our method of packing was not satisfactory and considerable mold developed. However, in subsequent tests mold has not been a noticeable problem.

Each of these methods would complicate harvest and storage procedures on most farms. But the results encourage us to continue to investigate these methods for storing high moisture corn whole in bunker silos.

(4) Ground snapped corn--Ground snapped corn field chopped through a recutter screen which chopped the cob and shuck rather fine but left considerable whole grain kept well and made excellent appearing high moisture corn. Without additional grain, rate and efficiency of gain was substantially below dry corn (Table 8). Adding OLBW after 56 days on feed to bring the roughage content of the ration from about 23% of the dry matter to about 10% of the dry matter increased rate of gain by about .8 lb per head daily for the last 52 days of the test, narrowing the spread from control significantly.

RUMINAL AND METABOLIC RESPONSES TO HIGH MOISTURE CORN STORED IN VARIOUS WAYS

In the trial (Koers, 1973) conducted in 1971 (tables 1, 2, 4, 5 and 6) dry corn (DR) was compared to harvested high moisture corn ground and stored in a bunker silo (HMGC) at 29 or 35% moisture content and 24% moisture corn stored whole in an oxygen limiting silo but fed ground (WHMCG). Gains of cattle fed DR and WHMCG were significantly greater than the HMGC treatments. There were differences in amount of feed consumed. Cattle fed DR consumed significantly more feed than those eating high moisture corns. Animals consumed significantly more WHMCG ration than the HMGC rations. There was a significantly higher consumption of the 29% HMGC than of the 35% HMGC.

A significantly higher incidence of abscessed liver was observed with the HMGC treatments than for the WHMCG. Feeding 35% HMGC resulted in significantly more condemned livers than with 29% HMGC.

Rumen samples from five steers per treatment were obtained for pH and lactate analysis (table 10). Cattle consuming HMGC had significantly lower rumen pH than those receiving DR or WHMCG. The rumen lactate levels were not different, even though lactate levels in the corns were somewhat different (DR = .10%, WHMCG = .50%, 29% HMGC = .31% and 35% HMGC = 1.39%).

In the 1973 trial (Barney, 1974) dry (14% moisture) corn fed whole (WDC) was compared to harvested high moisture (25% moisture) corn stored in an oxygen limiting silo and fed whole (WHMC), harvested high moisture (25% moisture) corn ground and stored in a bunker silo (HMGC) and 70% WHMC + 30% HMGC (HM-70-30-C) mixed and stored in a bunker silo. Two additional treatments included HMGC plus 2% bentonite added at time of feeding (HMGC + B) and HMGC plus 2% limestone added at time of feeding (HMGC + L).

The cattle on all treatments gained at similar rates irrespective of the type of corn consumed (table 11). The only significant difference found was that cattle eating WDC had a lower feed requirement per unit gain than HMGC + L and HMGC + B.

In a digestion trial conducted with lambs dry matter digestibility was significantly higher for WDC and WHMC than for HMGC (table 12).

A study of effect of type of corn on rumen pH indicated that across all sampling hours WDC and WHMC resulted in significantly higher rumen pH than did HMGC, HMGC + B and HMGC + L (table 13). HM-70-30-C resulted in significantly higher rumen pH than HMGC and HMGC + L. Inspection of pH values at various hours postfeeding revealed that WHMC and HM-70-30-C tended to produce the same rumen pH values as WDC.

At 2 hr postfeeding WDC, WHMC and HM-70-30-C had significantly higher rumen pH values than HMGC, HMGC + B and HMGC + L.

At 4 hr WDC, WHMC and HM-70-30-C resulted in higher rumen pH values than HMGC and HMGC + L.

At 6 hr WDC and WHMC produced higher pH than HMGC and HMGC + L.

Rumen lactate levels (table 13) were significantly higher for HMGC + L than all other treatments except HMGC across all sampling times. At 2 hr WDC, WHMC and HM-70-30-C had lower lactate than HMGC + L. HM-70-30-C had significantly lower lactate than HMGC + L.

At 4 hr postfeeding rumen lactate was lower for WDC, HMGC + B and HM-70-30-C than with HMGC + L. WHMC and HM-70-30-C had significantly lower lactate than HMGC.

At 6 hr WDC, WHMC, HMGC + B and HM-70-30-C had significantly lower lactate than HMGC + L.

As was observed with rumen pH the high moisture corn stored whole or partially whole tended to produce similar lactate levels as WDC.

The addition of bentonite to HMGC ration at feeding time lowered lactate as compared to HMGC or with limestone added at time of feeding. The addition of limestone raised rumen pH slightly as did bentonite but in contrast to bentonite, limestone raised lactate level at all hours.

Observation of rumen pH and lactate levels over a number of days indicated that on day one WDC had a significantly higher pH than did HMGC and HMGC + L. HMGC + L had a higher lactate level than the other treatments. On day 5 pH values for WDC, WHMC and HM-70-30-C were significantly higher than for the HMGC. HMGC and HMGC + L had significantly higher lactate values than HMGC + B.

On day 18 WDC and WHMC had pH values significantly higher than all three of the high moisture ground corn treatments. The HM-70-30-C had a significantly higher pH than did HMGC + L.

Lactate levels were not greatly different except that HMGC + L was significantly higher than other treatments.

On day 5 the HMGC and HMGC + L had significantly higher lactate values than other treatments.

On day 18 no real differences existed in lactate levels for treatments.

The data indicate that there is no adaptation required for the WDC, WHMC and HM-70-30-C but between 5 and 18 days is required for the animals to adjust to the high moisture corn stored ground in terms of rumen pH and lactate values.

Rumen ammonia and blood urea data (table 14) show WHMC had a significantly higher concentration of rumen NH_3 than did HMGC at 2 and 4 hr postfeeding and on day one and day 18 of the trial.

Blood urea nitrogen for all hours was significantly higher for WHMC than for high moisture corn stored ground.

The higher rumen NH_3 for WHMC and also for HM-70-30-C poses the question of whether these corns have more soluble protein than the high moisture corn stored ground or whether the high moisture corn stored ground loses some of the nitrogen during storage.

WHMC had a significantly higher percent N digestibility than all other treatments (table 15). WDC and HM-70-30-C had a significantly higher percent N digestibility than the HMGC and HMGC + B. The higher digestibility of WHMC compared to ground corn may support the idea of less soluble N in ground corn.

The rumen fermentation and lamb metabolism studies indicate that WHMC is more like WDC and unlike HMGC. The problems of low pH and high lactate levels apparently are related to the ground corn method of corn storage. The animal gains and efficiency of feed utilization also showed WHMC more like WDC than HMGC.

The problems of high moisture corn feeding that need to be solved appear to be associated with corn that is stored in the ground form.

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IN VITRO EVALUATION OF HIGH MOISTURE CORN STORAGE FACILITIES AT THE NORTHEAST STATION[1]

Samples of high moisture corn were obtained from the Northeast Station at Concord for *in vitro* analysis to characterize differences, if any, which types of high moisture corn storage might cause.

The types of storage were:

1. Whole high moisture corn (WHMC) in an oxygen limiting silo.
2. High moisture ground corn (HMGC) in an oxygen limiting silo.
3. 70% whole high moisture corn and 30% ground corn stored in a bunker silo (HM-70-30-C).
4. Whole high moisture corn and alfalfa stored in a bunker silo.

Samples were taken at different depths in the bunker silos and oxygen limiting silos to see if any changes were occurring in the corn as it approached the face of the silo or in the case of the oxygen limiting silo, the top of the silo, The WHMC samples were taken at the beginning and end of an unloading for feeding.

The samples were transported to Lincoln in a container with dry ice. All samples were freeze ground and the analyses performed on the wet samples. The high moisture corn samples were analyzed for pH, *in vitro* dry matter disappearance (IVDMD) at 8 and 48 hours, *in vitro* lactic acid production and dry matter (table 16).

The high moisture corn stored with the alfalfa haylage showed little changes in all parameters studied as the silo was sampled from the face to a depth of 29".

The 8 hours IVDMD, a measure of the rate of *in vitro* fermentation, did not differ as sampling depth increased. The 48 hours IVDMD or total digestibility also was not different. There were no significant changes in dry matter or pH as depth of sampling increased. The same can be said for *in vitro* lactate production, except for the 29" sample which was considerably lower than all other samples. The 29" sample was the depth of that silo where no heating could be detected. The *in vitro* lactate production from this silo is high compared to the rest of the high moisture corn storage facilities.

The WHMC did not show any differences in the two samples. The rate and total IVDMD were comparable to the whole corn and alfalfa storage. The pH of this sample was higher which indicates less fermentation had occurred. No detectable lactate was found with these samples.

The third storage facility studied was HM-70-30-C. The rate and total IVDMD did not change as the depth of sampling increased in this silo.

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[1]Farlin, Stanley D. and Robert Britton. Unpublished data. University of Nebraska, Lincoln.

The pH of these samples were high when compared to the other bunker silo and roughly the same as the WHMC. There was no detectable lactate when incubated *in vitro*.

The other high moisture corn storage that was sampled was HMGC. The first two samples, 2 and 4", are probably not representative of the silo in general because they were moldy and had an off odor. These samples had a low rate of IVDMD and an abnormally high pH. The rate of IVDMD from 8" to 30" increased from 33.1 to 40.7%. The total IVDMD was not different in these samples, however. The pH of these samples was increasing as the depth of sampling increased. The *in vitro* lactate data tended to increase as sampling depth increased but the relationship is not clear.

A control dry corn is presented at the bottom of the table for comparative purposes.

Table 1. High Moisture Shelled Corn Stored Ground vs Dry Corn Rolled Before Feeding.

End Date	Daily Gain Dry	Daily Gain Hi H_2O	Feed/Gain[1] Dry	Feed/Gain[1] Hi H_2O	Adv. for Moist Grain Gain	Adv. for Moist Grain Eff.
	lb.	lb.	lb.	lb.	%	%
Apr. 70	2.1 (45)[2]	2.0 (90)[3]	8.2	8.9	- 4	- 8
Aug. 70	2.6 (30)	2.2 (30)[3]	6.7	8.1	-15	-17
July 71	2.7 (44)	2.4 (88)[4]	6.8	7.0	-10	- 2
Apr. 72	1.9 (40)	1.7 (40)[4]	10.0	11.1	- 8	- 8
July 72	3.1 (40)	2.9 (40)[4]	6.3	6.7	- 8	- 6
July 73	2.4 (20)	2.2 (60)[3]	7.4	8.1	- 8	- 8
Avg.					- 9	- 8

[1]Average daily feed intake was 18.2 and 18.1 lb for dry and hi H_2O respectively.

[2]No. of cattle in parentheses.

[3]Stored in upright silo with top unloader.

[4]Stored in bunker silo.

Table 2. Effect of Moisture Level on Results From Ground High Moisture Corn.

End Date	Gain Med. H_2O	Gain Hi H_2O	Feed/Gain[1] Med. H_2O	Feed/Gain[1] Hi H_2O	Adv. to Hi H_2O Gain	Adv. to Hi H_2O Eff.
	lb.	lb.	lb.	lb.	%	%
Apr. 70	2.0	2.0	9.1	8.7	0	+ 4
July 71	2.4	2.4	7.1	6.8	0	+ 4
Apr. 72	1.6	1.7	9.8	9.0	+ 4	+ 8
Apr. 72	1.6	1.7	11.1	10.3	+ 7	+ 7
July 72	2.9	2.8	6.8	6.6	- 4	+ 3
Jan. 76[2]	1.8	2.0	11.4	10.3	+10	+10
May 76[2]	2.5	2.2	8.0	8.5	-10	- 6
Avg.					+ 1	+ 4

[1]Corn consumption was slightly higher for the medium moisture product.

[2]30 ground - 70% whole.

Table 3. Effect of Additional Roughage When Feeding Ground High Moisture Corn.

End Date	Daily Gain		Feed/Gain[1]		Adv. for Moist Grain	
	Dry	Hi H_2O	Dry	Hi H_2O	Gain	Eff.
	lb.	lb.	lb.	lb.	%	%
Aug. 70						
1 1/2 C. Sil.[2]	2.6	2.2	6.7	8.1	-15	-17
3# C. Sil.[2]	2.7	2.5	6.8	7.6	- 6	-12

[1]Average daily corn dry matter intake slightly higher for high moisture corn.

[2]30 head per group.

Table 4. High Moisture Corn Stored Whole and Rolled Before Feeding vs Dry Rolled Corn.

End Date	Daily Gain		Feed/Gain		Adv. for Moist Grain	
	Dry	Hi H_2O	Dry	Hi H_2O	Gain	Eff.
	lb.	lb.	lb.	lb.	%	%
Apr. 70	2.1	2.2	8.2	8.0	+ 5	+ 2
Aug. 70	2.7	2.6	6.8	6.9	- 4	- 1
July 71	2.7	2.8[1]	6.8	6.6	+ 4	+ 3
Apr. 72	1.9	2.0	10.0	9.2	+ 5	+ 8
July 72	3.1	3.0[1]	6.3	6.4	- 3	- 2
Avg.					+ 1	+ 2

[1]Considerable mold before end of trial.

Table 5. High Moisture Corn Stored Whole Fed Whole vs Dry Corn Whole or Rolled Before Feeding.

End Date	Daily Gain Dry	Daily Gain Hi H_2O	Feed/Gain Dry	Feed/Gain Hi H_2O	Adv. for Moist Grain Gain	Adv. for Moist Grain Eff.
	lb.	lb.	lb.	lb.	%	%
Apr. 70	2.1	2.5	8.2	7.8	+19	+ 5
July 71	2.7	2.9[1]	6.8	6.3	+ 7	+ 7
Apr. 72	1.9	2.0	9.9	9.4	+ 5	+ 5
July 72	3.2	3.3[1]	6.4	6.2	+ 3	+ 3
July 73	2.4	2.3	7.4	7.7	- 4	- 4
May 74	2.9	3.0	6.8	6.4	+ 3	+ 6
Jan. 76	1.8	2.1	11.7	10.1	+17	+14
May 76	2.5	2.6	7.6	7.3	+ 4	+ 4
Avg.					+ 7	+ 5

[1]Considerable mold before end of trial.

Table 6. High Moisture Corn Stored Whole Fed Whole vs Rolled Before Feeding.

End Date	Gain Whole	Gain Rolled	Feed/Gain Whole	Feed/Gain Rolled	Advantage to Whole	
	lb.	lb.	lb.	lb.	%	%
July 71[1]	2.9	2.9	6.3	6.5	0	+ 3
Mar. 72	2.2	2.0	8.7	9.2	+ 5	+ 6
Mar. 72*	1.9	1.8	10.2	10.0	+ 4	- 2
July 72*	3.2	2.9	6.2	6.8	+14	+10
July 72[1]	3.3	3.0	6.2	6.4	+ 7	+ 3
Aug. 73	2.2	2.2	8.2	8.2	0	0
Avg.					+ 5	+ 3

*Acid treated.

[1]Considerable mold before end of trial.

Table 7. High Moisture Corn Stored Whole in Bunker Silos vs Dry Control.

End Date	Gain		Feed/Gain		Adv. of Tr. Over Control	
	Control	Treated	Control	Treated	Gain	Eff.
	lb.	lb.	lb.	lb.	%	%
			30% Ground -- 70% Whole			
July 73	2.4	2.3*	7.4	8.0*	- 4	- 8
Jan. 76	1.8	1.9	11.7	10.8	+ 9	+ 9
May 76	2.5	2.4	7.6	8.2	- 4	- 9
*Some molding because of poor pack.						
			90% Whole -- 10% Alfalfa Haylage in Bunker			
July 73	2.4	2.4*	7.4	7.7*	0	- 4
May 74	2.9	3.1	6.8	6.5	+ 7	+ 4
*Some mold in alfalfa.						
			82% Whole -- 18% Corn Silage in Bunker			
May 74	2.9	2.9	6.8	6.3	0	+ 7

Table 8. Miscellaneous Treatments to High Moisture Corn.

End Date	Gain		Feed/Gain		Adv. of Treated	
	Control	Treated	Control	Treated	Gain	Eff.
	lb.	lb.	lb.	lb.	%	%
			Ground Snapped Corn			
Feb. 74	2.9	2.4	6.8	8.0	-17	-18
			Ground Snapped 56 Da. Then Added Hi H_2O Shelled Corn			
Feb. 74	2.9	2.8	6.8	7.1	- 5	- 3
			Bentonite			
July 73	2.2	2.2	8.0	8.2	0	- 2
May 74	3.0	3.0	6.4	6.6	0	- 2
			Limestone			
July 73	2.2	2.1	8.0	8.2	- 4	- 2
July 73	2.3	2.2	8.0	8.3	- 4	- 4
July 73	2.4	2.2	7.7	8.0	- 8	- 4

TABLE 9

PERFORMANCE OF STEERS FED DRY OR HIGH MOISTURE CORN STORED UNDER DIFFERING CONDITIONS[1] (TRIAL 1)

	TREATMENT[2]			
Item	DR	WHMCG	29% HMGC	35% HMGC
No. steers	44	44	44	44
Initial weight, kg	348	350	351	351
Final weight,[3] kg	504	512	492	488
Avg. daily gain,[4] kg	1.23	1.28	1.11	1.08
Avg. daily feed,[6] kg	8.41	8.53	7.81	7.24
Kg feed/kg gain[4]	6.87	6.65	7.07	6.75
Condemned livers, %	11.38	9.10	18.20	34.12
Dressing %	61.75	61.67	61.92	61.37
Carcass grade score[5]	18.42	17.58	17.70	17.67

[1]Trial length 127 days.

[2]DR = 14% moisture corn stored whole in a conventional grain bin; WHMCG = 24% moisture corn stored whole in an oxygen limiting grain bin fed ground; HMGC = 29% moisture corn ensiled ground in a bunker silo; HMGC - 35% moisture corn ensiled ground in a bunker silo.

[3]Final weight adjusted to 62% carcass dressing percent.

[4]Average daily gain and feed per gain based on adjusted final weight.

[5]Carcass grade numerical values: 16 = high good; 17 = low choice; 18 = average choice; 19 = high choice.

[6]Dry matter basis.

TABLE 10

RUMEN FERMENTATION DATA FROM STEERS FED DRY OR HIGH MOISTURE CORN STORED UNDER DIFFERING CONDITIONS (TRIAL I)

Hours after feeding	pH	Histamine	Lactate
		ug/ml	ug/ml
Ration 1. 12% H_2O stored whole			
1	6.29	.70	767
3	6.11	.44	675
Average	6.20	.57	721
Ration 2. 29% H_2O stored whole in O_2 limiting silo			
1	6.60	.76	541
3	6.60	.57	2321
Average	6.60	.67	1431
Ration 3. 24% H_2O, ensiled ground in bunker silo			
1	5.93	1.64	642
3	5.81	.70	489
Average	5.87	1.17	565
Ration 4. 35% H_2O, ensiled ground in bunker silo			
1	5.87	1.77	625
3	6.45	.27	495
Average	6.16	1.02	560

TABLE 11

INFLUENCE OF CORN TREATMENT UPON PERFORMANCE OF CATTLE (REPLICATION 1, 140 DAYS)

	WDC	WHMC	HMGC	HMGC+ L	HMGC+ B	HM-70-30-C
No. steers	10	10	10	10	9	10
Initial weight, kg	349	351	351	347	350	347
Adj. final weight,[1] kg	494	505	487	483	487	496
Avg. daily gain, kg	1.04	1.10	0.97	0.97	0.98	1.06
Daily feed consumption, kg	8.08	8.44	8.26	7.99	8.44	8.58
Feed/kg gain	7.8	7.7	8.5	8.2	8.6	8.1
Quality grade[2]	12.6	12.4	11.7	12.3	11.8	12.7
Yield grade	3.5	3.7	3.3	3.4	3.4	3.6

[1]Final weights adjusted to 62 percent dressing percentage.

[2]Carcass grade numerical values: C+, 14; C^{o}, 13; C-, 12; G+, 11; G^{o}, 10; G-, 9.

TABLE 12

INFLUENCE OF CORN TREATMENT
UPON DRY MATTER DIGESTIBILITY

	DMD %
WDC	83.41[a,b]
WHMC	86.32[a]
HMGC	78.75[c]
HMGC+L	82.19[a,b,c]
HMGC+B	77.84[c]
HM-70-30-C	80.45[b.c]

[a,b,c]Values with different superscripts are significantly different ($P < .05$)

TABLE 13

INFLUENCE OF CORN TREATMENT UPON
RUMEN pH AND RUMEN LACTIC ACID

	pH	Lactate[1]
WDC	5.88[a,b]	36.17[a]
WHMC	5.89[a]	17.62[a]
HMGC	5.40[d]	103.81[a,b]
HMGC+L	5.47[d]	158.84[b]
HMGC+B	5.58[c]	38.86[a]
HM-70-30-C	5.79[a,b,c]	19.50[a]

[1]mg lactate/L.

[a,b,c,d]Values in the same column with different superscripts are significantly different ($P < .05$).

TABLE 14

INFLUENCE OF CORN TREATMENT UPON RUMEN AMMONIA AND BLOOD UREA

	NH_3[1]	Blood urea[2]
WDC	3.56[a]	11.52[a,b,c]
WHMC	6.17[a]	13.12[a]
HMGC	2.12[b]	8.82[c]
HMGC+L	2.36[a,b]	9.39[b,c]
HMGC+B	2.66[a]	8.69[c]
HM-70-30-C	5.67[a]	12.39[a,b]

[1] mg NH_3-N/100 ml

[2] mg urea-N/100 ml

[a,b,c] Values in the same column with different superscripts are significantly different ($P < .05$).

TABLE 15

INFLUENCE OF CORN TREATMENT UPON NITROGEN RETENTION (PERCENT OF INTAKE) AND NITROGEN DIGESTIBILITY

	% N-retained[1]	N-digestibility
WDC	28.92[a]	68.08[b]
WHMC	25.55[a]	73.07[a]
HMGC	21.59[a,b]	59.62[c]
HMGC+L	28.12[a]	63.47[b,c]
HMGC+B	17.10[b]	54.02[d]
HM-70-30-C	25.78[a]	66.03[b]

[1] Nitrogen retained as percent of intake.

[a,b,c,d] Values in the same column with different superscripts are significantly different ($P < .05$).

TABLE 16
ANALYSIS OF HIGH MOISTURE CORN[a]
FROM NORTHEAST STATION

Samples		Sample no.	IVDMD hr 8	IVDMD hr 48	DM[b]	pH	Lactate[c] ug/ml
Whole corn & alf.	Surface	2	34.06	88.39	77.80	4.80	98.7
" " "	6"	4	36.66	87.32	76.53	4.70	132.7
" " "	12"	1	38.36	89.06	77.17	4.80	119.0
" " "	16"	6	35.59	88.79	77.27	4.75	104.8
" " "	18"	8	35.42	88.48	76.31	4.75	170.7
" " "	29" NH	10	36.20	87.47	77.31	4.90	34.6
WHMC	Top of bin	7	37.20	87.49	76.36	5.95	ND[d]
"	End of bin	9	37.22	87.26	76.50	5.95	ND
HM-70-30-C	Surface	14	33.25	87.03	76.74	6.30	ND
" "	1st 6"	21	34.52	87.34	78.97	5.90	ND
" "	6"	20	31.97	86.61	76.67	6.30	ND
" "	12"	11	32.56	85.71	77.43	6.20	ND
" "	18"	19	31.13	85.99	77.45	6.05	ND
" "	24" NH	13	33.93	86.65	76.85	5.90	ND
HMGC	2"	15	31.36	89.37	75.47	6.70	ND
"	4"	18	31.13	89.05	79.10	6.60	ND
"	8"	17	33.11	90.22	74.40	4.75	ND
"	12-16"	16	36.55	91.28	74.03	4.60	16.8
"	24"	3	38.60	91.23	75.56	4.70	ND
"	30"	5	40.67	90.26	74.26	4.90	33.1
"	40" NH	12	38.75	91.57	74.34	5.05	12.2
Dry corn			37.45	87.07	87.18	6.10	21.9

[a]All analyses performed on a freeze ground fresh sample.

[b]Oven dry matter not corrected for loss due to volatile dry matter.

[c]One gram of dry matter incubated with 15 ml strained rumen fluid and 15 ml McDougall's buffer for one hour.

[d]ND = not detectable

"CHEMICAL PRESERVATION OF HIGH-MOISTURE GRAINS"

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The harvesting, storage and feeding of high-moisture (HM) grains, especially corn, have become both practical and widespread in recent years. The short growing season throughout the main Corn Belt has brought about a reliance on drying systems which become overloaded at peak harvest times. A wet harvest season and/or propane shortages can spell disaster to farmers trying to harvest a 6 billion bushel corn crop. Chemical preservation of HM grain is an alternative to conventional methods of harvesting and storing grain and has contributed to the increased use of HM grains.

The concept of chemical preservation of feedstuffs is not new. Farmers in Scandinavian countries have been using mineral acids to improve the quality of silage for as long as 50 years. Chemical preservation of HM grain in this country is a recent development. For the past six years, Celanese Chemical Company has been testing and developing preservatives. Many innovations, outdoor uncovered storage for example, have been developed in this program to give farmers and feedlot operators greater flexibility in their harvesting and feeding programs.

There are many advantages to using chemical preservation of feed grains. Corn can be harvested after the kernels have reached physiological maturity at a moisture content of about 35%. This is an advantage to fall harvesting schedules and protection against losses due to potentially poor weather later in the season. Harvesting yield is increased by about 5-10% when grain is harvested early. Marx[1] (1973) showed that barley yields 7% more dry matter per acre when harvested high moisture than barley allowed to dry in the field. Treatment costs of preservatives are less than conventional drying and there are no bottlenecks since treatment is rapid. Large capital investments are not required. Applicator systems are far less expensive than drying operations. Storage shrink is practically eliminated since chemically preserved HM grain does not ferment or respire. Treated grain can be transported to other locations and fed from self feeders without risk of spoilage. Jones[2], *et al* (1974) reviewed the nutritional value of chemically preserved HM grain and concluded that feed efficiency of beef cattle consuming HM grain was superior to that of cattle consuming dry grain. On a dry matter basis, dairy

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(1) Marx, G.C., 1973, "Harvesting, Storing and Feeding High-Moisture Barley to Lactating Dairy Cows," Mimeo, Paper No. 8267, *Scientific Journal Series*, Minnesota Agricultural Experiment Station.

(2) Jones, G.M., D.N. Mowat, J.I. Elliot & E.T. Moran, Jr., "Organic Acid Preservation of High-Moisture Corn & Other Grains & The Nutritional Value: A Review," *Can. J. Anim. Sci.*, 54:499, 1974.

cattle, swine and poultry perform equally well on chemically preserved HM grain as on dry grain. The added bonus is that chemically preserved grains do not support growth of mycotoxin-producing organisms. The detrimental effects of mycotoxins on animal performance has only been recently appreciated. Chemical preservation and proper storage methods inhibit the growth of mycotoxin-producing organisms from harvest right until the grain is consumed by an animal. Chemical preservation of HM grain is also much less energy consuming than drying. A comparison of energy consumption of conventional dryers to that of ChemStor® III liquid preservative treatment of 25% moisture corn shows that chemical treatment consumes about one-third the energy of conventional drying (Figure 1).

Chemically treated corn also has several disadvantages. Since it is classed as sample grade, it does not enter normal channels of grain commerce. This is not serious since most of the treated grain is fed by the farmer or sold to feedlots. Chemicals used to treat HM grains are somewhat corrosive to machinery, and great care must be exercised in the handling of these chemicals.

Propionic acid is the main component of most commercial preservatives. Celanese Chemical Company developed ChemStor III grain preservative, which consists of 70% propionic acid and 30% stabilized formalin (Figure 2). Our research over the past four years has shown that this blend is superior to straight propionic acid since it controls both molds and bacteria in stored grain. Propionic acid is mainly a fungicide, and bacteria are usually responsible for initiating a spoilage sequence. Propionate salts are less efficacious than the acid.

Proper grain preservation with chemicals consists of four major factors: adequate treatment levels, proper application, suitable storage, and good grain management. Recommended treatment rates for ChemStor III grain preservative are shown on Table I. The improved nature of the preservative allows treatment within broad grain moisture intervals. The six months' recommendation means that the grain is to be completely fed out within the six-month storage period. If the grain temperature is above 70°F, these rates should be increased 0.1% for each 10° above 70°F because spoilage organisms are more virulent at elevated temperatures. Grain stored in outdoor piles must be treated with 1.1% ChemStor III liquid preservative for all moisture levels and must be completely fed out within six months.

Proper application requires good mixing of the grain and preservative as the grain goes into storage. Whenever possible, as in elevators, the grain should be turned one time after treatment to thoroughly mix the grain. Most farm applicators will treat up to 1,000 bushels per hour. Larger systems will treat up to 7,000 bushels per hour. These are used in feedlots and grain elevators.

A variety of storage systems can be used. HM-treated grain can be stored in elevator silos, flat storage grain bins, wooden structures, or in outside piles with proper management. Outside piles should be on well-drained concrete or asphalt slabs with access to the perimeter. The piles should be symmetrical without peaks or valleys. The grain should be fed from around the pile, continually renewing the surface until it is fed out after six months.

Galvanized or steel bins must be protected by a suitable acid-resistant coating to prevent corrosion. This applies to the ceiling as well as the walls, since condensing vapors from the grain will react with the metal and damage the bins.

Good stored grain management is a key to chemically treated HM grain. Start with a clean storage site. Monitor the stored grain on a regular basis for early detection of heating. The head space over the grain should be ventilated to prevent sweating. Control moisture migration.

Undertreatment or dilution of the preservative in marginally treated piles by moisture migration can initiate spoilage of the treated grain. Moisture migration is brought about by large temperature differentials between warm grain and cold air. Convection currents within the pile will move moisture. This can be controlled by cooling the grain to 55°F or less, ventilating the head space, and by using low-profile piles.

Chemical preservation of HM grains, forages and other feedstuffs is now an accepted practice and offers unique opportunities. For example, treatment and storage of chemically preserved grain is used in grain banking programs in Kansas with great success.

Preservatives are now being researched for utilization of other feedstuffs, such as recycled manure, spent brewers grains, alfalfa pellets, and finished feeds to name a few.

The use of preservatives provides tremendous resource energy savings, and we can expect to see increased use of chemically preserved HM grain in the future.

TABLE I

Recommended rates for ChemStor®III preservative are:

Grain Moisture Range, %	Treatment rates if grain is to be fed out within: 6 months	12 months
20 or less	0.5%	0.7%
21-30	0.7%	0.9%
31-35	0.9%	1.2%
36-40	1.1%	1.4%

If grain temperature is above 70°F when treated, increase the above rates by 0.1% for each 10°F above 70°F.

FIGURE 1

COMPARISON OF ENERGY CONSUMPTION

Chemical Preservation vs High Capacity Hot Air Drying for 25% Moisture Content Grain

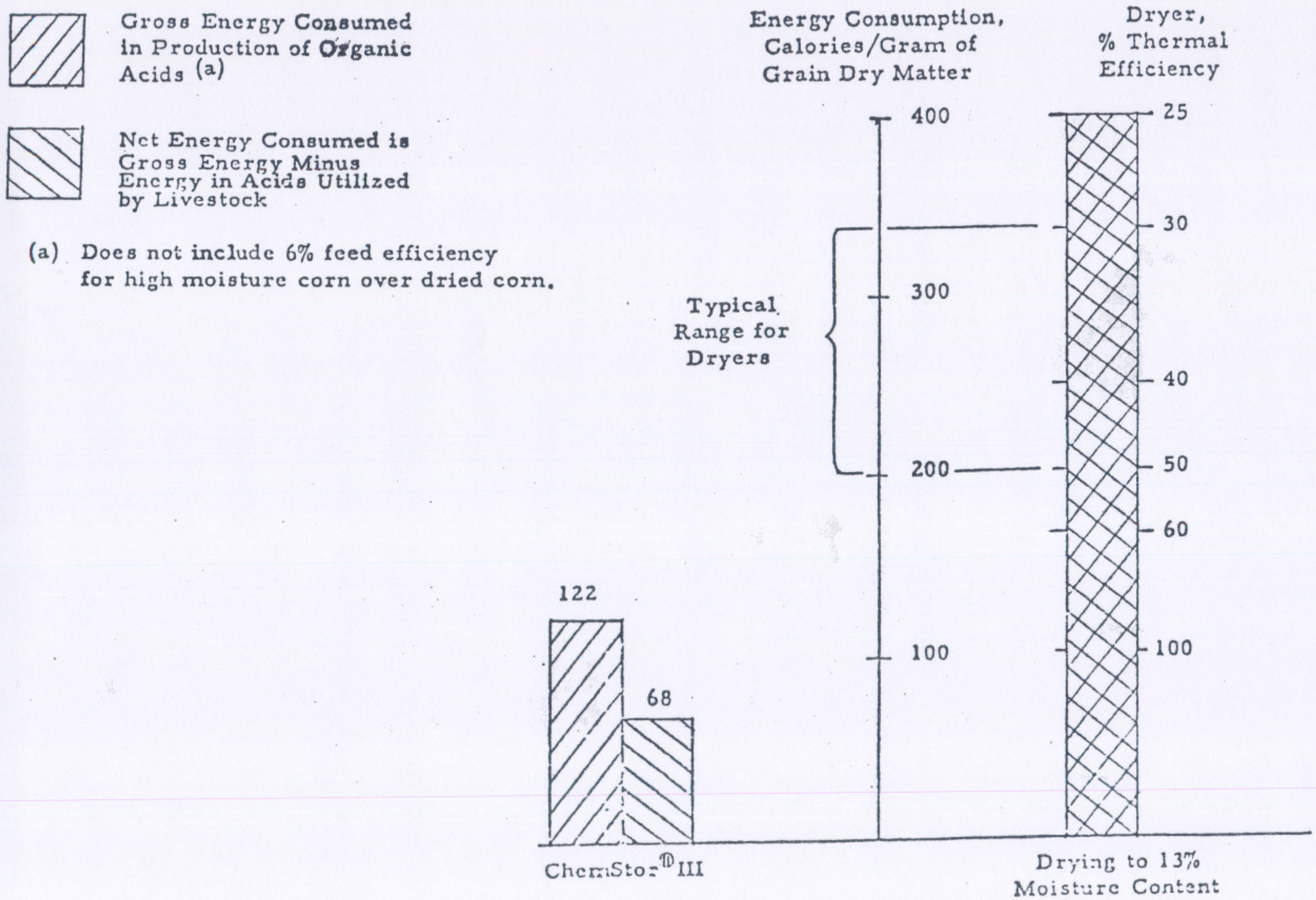

FIGURE 2

CHEMSTOR® III

LIQUID PRESERVATIVE FOR HIGH MOISTURE CORN, SORGHUM, WHEAT, OATS AND BARLEY.

TO BE USED IN ANIMAL FEED ONLY

ACTIVE INGREDIENTS: Propionic acid 67% Min., Formaldehyde 10% Min.
INERT INGREDIENTS: 23% Max. Contains Methanol

DIRECTIONS: To ensure complete coverage of the grain, apply the product with a pressure sprayer system. Determine the moisture level of the harvested feed grain, establish applicator grain throughout and set flow to apply the proper amount of ChemStor® III liquid preservative as follows:

Grain Moisture Range, %	Treatment rates if grain is to be fed out within: 6 months	12 months
20 or less	0.5%	0.7%
21-30	0.7%	0.9%
31-35	0.9%	1.2%
36-40	1.1%	1.4%

If grain temperature is above 70°F when treated, increase the above rates by 0.1% for each 10°F. above 70°F. Grain should be treated within 6 hours after harvest.

Do not mix treated grain with untreated grain in the same storage facility. Good harvesting and storage practices should always be followed in the handling, treatment, and storage of ChemStor® III treated high moisture grain. Do not enter storage facilities without adequate ventilation. Do not treat corn or other cereal grains which might be used for seed, malting purposes or human consumption. Treated corn and other cereal grains are to be *used for animal feed only.*

DANGER ☠ POISON ☠ | **CAUSES SEVERE BURNS**
KEEP OUT OF REACH OF CHILDREN

Harmful or fatal if swallowed. Do not get liquid or vapor in eyes, on skin, or clothing. Use in well ventilated area and do not inhale. Wear goggles, rubber gloves and protective clothing when handling ChemStor® III. In case of contact, immediately flush skin or eyes with plenty of water for at least 15 minutes. For eyes, or after swallowing get immediate medical attention. If swallowed, do not induce vomiting. Give large amounts of water followed by milk or egg white beaten with water. Methanol may cause blindness. Vapor harmful.

After contents have been removed, drums should be washed and completely drained. Do not contaminate water by cleaning of equipment, or disposal of wastes. Do not use, pour, spill or store near heat or open flame. Drums not to be reused for any product other than ChemStor® III. Read entire label. Use strictly in accordance with danger statements and directions, and with applicable state and federal regulations.

E.P.A. REG. NO. 11558-2

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INFLUENCE OF MATURITY AND MOISTURE CONTENT ON THE FERMENTATION OF HIGH MOISTURE CORN

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Ensiled high moisture corn is widely used as a feedstuff by cattle feeders in the United States. Its popularity as a feedstuff is due to several management, economic and nutritional advantages. These advantages for ensiled high moisture corn may be listed as follows:

A. Earlier harvest, which results in:

1. reduced field losses
2. a longer harvest period
3. more time to complete fall plowing
4. increased use of corn stalks by beef cows

B. Reduced energy needs

C. May allow the use of higher yielding, later maturing corn varieties

D. Results in a highly palatable feed

E. Less separation of ration ingredients in the bunk

F. Improved feed efficiency

However, ensiled high moisture corn has lost much of its market flexibility and must be used as a livestock feed. Storage losses may be higher, if proper ensiling conditions are not followed, than for dry corn grain. Also, an adequate rate of feeding must occur if storage losses are to be minimized. Since these disadvantages may be easily overcome, and since the advantages for ensiled high moisture corn are significant, it is easy to understand why this feedstuff has become popular.

It is the intent of this paper to review the influence of stage of maturity and moisture content on the fermentation of corn grain.

Maturity

Corn maturity may be an important consideration in two instances. First, producers may plant late maturing varieties so as to obtain maximum yields. In northern climates this increases the risk of a killing frost occurring prior to the time that the grain is mature. Secondly, producers may be concerned about harvesting corn grain prior to full maturity, as they attempt to increase the length of the harvest period. Thus, it may be of interest to review the influence of maturity on the composition and energy value of corn grain, and to review the moisture content of corn grain at the point of physiological maturity.

Thornton et al. (1969a,b) hand picked corn at early milk, early dough, mid dent and mature stages of kernel maturity. Descriptions of the corn grain are presented in table 1. Shelling percentages of dried ear corn were 57.1, 61.9, 80.0 and 81.0%, for early milk, early dough, mid dent and mature, respectively. Bushel weights of dried shelled corn were 35, 47, 55 and 58 lb. Moisture contents of the corn grain at respective stages of maturity were 79.1, 64.3, 44.5 and 23.4%.

Proximate, starch, cell wall constituents and gross energy analyses, on a dry matter basis, (table 2) for crude protein decreased from 15.6 to 10.9%, ether extract increased from 3.0 to 4.9%, crude fiber decreased from 5.4 to 2.1%, ash decreased from 2.8 to 1.5% and nitrogen-free extract increased from 72.2 to 80.6% as the corn grain progressed from an early milk to mature stage of maturity. Starch contents increased and cell wall constituents decreased with advancing maturity.

Weights of proximate nutrients per 100 kernels of corn (table 3) showed that dry matter increased from 4.54 to 25.06 g, crude protein increased from 0.70 to 2.70 g, ether extract increased from 0.16 to 1.28 g, crude fiber increased from 0.21 to 0.55 g, ash increased from 0.13 to 0.37 g and nitrogen-free extract increased from 3.34 to 20.16 g as the corn progressed from the early milk to the mature stage of maturity. Data in table 4 show that crude fiber, cell wall constituents and ash were deposited in the corn kernel somewhat earlier than other nutrients. Starch and ether extract were deposited at later stages of maturity than other nutrients.

Digestibilities of organic matter, total carbohydrates (crude fiber and NFE), ether extract and energy increased as corn maturity increased. TDN and digestible energy contents increased with advancing maturity (table 5). Early milk corn (35 lb/bu) contained 91.3% as much TDN as mature corn, early dough corn (47 lb/bu) contained 94.0% as much TDN as mature corn and mid dent corn (55 lb/bu) contained 97.1% as much TDN as mature corn (58 lb/bu). Regression analyses indicated that the TDN value of corn grain was reduced 0.32 percentage units for each pound reduction in test weight below 54 lb/bu. Thus, these data show that immature corn has a reduced energy value, but that the reduction in energy value is less than expected.

Although the above data quantify the influence of maturity on the nutritive value of corn grain, it does not establish the moisture content at which physiological moisture was attained. Others (Dressureaux _et al._, 1948; Shaw and Thom, 1951; Kiesselbach, 1950; Rather and Marston, 1940; Aldrich, 1943) have reported that the moisture content of corn grain at the point of physiological maturity is between 30 and 44%. If a more narrow range is desired, it would probably be safe to assume that corn grain is fully mature when the kernels contain 35 to 40% moisture. A more positive method of determining physiological maturity is the development of the black layer in the tip of the corn kernel. When this layer is formed the corn is fully mature and further deposit of nutrients in the kernel does not occur.

In conclusion, under normal circumstances corn maturity should not be a concern of producers who harvest their corn grain for ensiling, since there is little reason to harvest corn grain at moisture contents above 30%. The influence of moisture contents below 30% moisture on the fermentation of corn grain will be discussed in the following section.

Moisture Content

In an effort to determine if the moisture content of high moisture corn influences the performance of feedlot cattle, we summarized the results of several trials. This summary (table 6) shows that the performance of cattle fed high moisture corn grain (less than 29% moisture) was superior (2.57 vs 2.53 lb/day gain; 583 vs 618 lb DM/100 lb gain) to the performance of cattle fed dry corn grain. Thus, the cattle fed ensiled high moisture corn gained 1.6% faster and required 5.3% less dry matter per 100 lb of gain than cattle fed dry corn grain.

When ensiled high moisture corn with more than 29% moisture was compared to dry corn grain, cattle fed the high moisture corn gained 6.1% slower (2.46 vs 2.62 lb/day) and were only 2.1% more efficient (797 vs 814 lb DM/100 lb gain) than cattle fed dry corn. Thus, it is apparent that the moisture content of ensiled corn grain is an important consideration and it may be useful to study the influence of moisture content on the fermentation of corn grain in an effort to explain the observed differences in the performance of feedlot cattle.

Goodrich <u>et</u> <u>al</u>. (1975) studied the influence of moisture content on the fermentation of rolled corn grain in laboratory silos. Moisture contents of 21.5, 27.5 and 33.1% were used in this trial. Dry matter loss increased from 2.7 to 5.6% of the dry matter ensiled and energy loss increased from 1.9 to 3.6% of the energy ensiled as the moisture content increased from

21.5 to 33.1% (table 7). Heuberger et al. (1959) reported dry matter losses of 2.16, 3.40 and 1.19% for corn grain ensiled at 24, 29 and 36% moisture. Gas production increased and pH declined as moisture content increased (table 7) indicating that the higher moisture corn grain had undergone more fermentation than the drier corn. Organic acid and ethanol contents also increased as moisture content of the corn grain increased, a further indication that the higher moisture content resulted in a more extensive fermentation. The acetic and lactic acid contents reported in table 7 are lower than those often reported for whole plant corn silage. The 0.15% butyric acid which was found in corn with 33.1% moisture may be higher than desired. Similar lactic and acetic acid levels were reported by Prigge et al. (1976) for ensiled ground corn grain.

Danley and Vetter (1974a,b) ensiled corn grain at 16, 18 and 22% moisture. Dry matter losses were 3.79, 1.38 and 3.50%, acetic acid contents were 0.144, 0.084 and 0.138%, propionic acid contents were 0.070, 0.037 and 0.064% and butyric acid contents were 0.097, 0.087 and 0.086% of corn dry matter for corn ensiled at 16, 18 and 22% moisture. In vitro digestibilities of dry matter and total carbohydrates were similar for corn ensiled at 16, 18 or 22% moisture.

Wilkinson et al. (1976) studied the influence of adding lactic and acetic acids to ensiled and unensiled (frozen) whole corn plant silage. Although their studies were not conducted with ensiled corn grain, this interesting report may aid in explaining some feedlot problems with ensiled feeds. Dry matter intakes and daily gains were reduced when the organic acids were added to the forage, and intakes and gains were lower for cattle fed ensiled corn plants than for those fed frozen corn plants. Dry matter digestibilities were not influenced by treatments, but urinary nitrogen losses were greater for ensiled and acid addition treatments than for frozen forage. These researchers summarized their data by stating, "Addition of acids may be detrimental to N balance via an effect on urinary ammonia excretion and acidification of the urine in response to the acid load, but further research is needed to elucidate the role of organic acids as factors affecting the nutritional value of ensiled forages. The depression in voluntary intake due to acid addition, and the slower rate of animal growth on the ensiled as compared to the frozen material indicate that ensiling techniques which minimize acidity and proteolysis appear desirable."

Thus, the periodic reports of cattle fed ensiled rations consuming less than expected amounts of dry matter and gaining slower than expected may be partly explained by the concepts presented in the above paper (Wilkinson et al., 1976). Cattle fed highly fermented rations (wet corn silage or corn silage plus ensiled high moisture corn) may be under acid stress and have lowered performance. Also, high moisture corn may not result in an excess acid load when it is fed in combination with certain feeds, such as alfalfa which has an alkaline ash, while when fed in combination with other feeds (those that result in high lactic acid productions) it may lower performance. Thus, acid load may be an important consideration in formulating cattle rations. Another explanation for the reduced feed intakes often observed when highly fermented feeds are fed is the increased nonprotein nitrogen levels which are found in fermented feeds. This subject will be discussed by Dr. Bergen and Dr. Prigge.

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Table 1. Description of Corn Grain at Various Stages of Maturity.

Item	Early milk	Early dough	Mid dent	Mature
Shelling percentage of dried ear corn	57.1	61.9	80.0	81.0
Weight/bu., lb.	35	47	55	58
Days from planting to picking	84	95	109	145
Days from silking to picking	17	28	42	78
Moisture content, %	79.1	64.3	44.5	23.4

Table 2. Chemical Composition, on a Dry Matter Basis, of Corn Grain at Various Stages of Maturity.

Item	Early milk	Early dough	Mid dent	Mature
	-----------	%	-----------	-----------
Crude protein	15.6	12.5	10.7	10.9
Ether extract	3.0	4.0	4.8	4.9
Crude fiber	5.4	3.3	2.5	2.1
Ash	2.8	2.3	1.7	1.5
Nitrogen-free-extract	72.2	77.9	80.3	80.6
Starch	47.4	55.0	58.7	63.7
Cell wall constituents	27.2	24.6	16.3	13.9

Table 3. Nutrients per 100 Kernels of Corn Grain at Various Stages of Maturity.

Item	Early milk	Early dough	Mid dent	Mature
	-----------	g	-----------	-----------
Dry matter	4.54	11.01	19.68	25.06
Crude protein	0.70	1.34	2.10	2.70
Ether extract	0.16	0.46	0.94	1.28
Crude fiber	0.21	0.35	0.51	0.55
Ash	0.13	0.26	0.34	0.37
Nitrogen-free-extract	3.34	8.60	15.79	20.16
Starch	2.15	6.06	11.55	15.96
Cell wall constituents	1.26	2.71	3.21	3.48
Gross energy	20.7 Kcal	49.99 Kcal	90.33 Kcal	114.77 Kcal

Table 4. Percentages of Nutrients Deposited at Various Stages of Maturity.

Item	Early milk	Early dough	Mid dent	Mature
	---------------	------ % ------	---------------	
Dry matter	18	44	79	100
Crude protein	26	50	78	100
Ether extract	12	36	73	100
Crude fiber	38	64	93	100
Ash	35	70	92	100
Nitrogen-free-extract	17	43	78	100
Starch	13	38	72	100
Cell wall constituents	36	78	92	100
Gross energy	18	44	79	100

Table 5. Average Apparent Digestion Coefficients of Corn Having Different Bushel Weights.

Item	Early milk	Early dough	Mid dent	Mature
No. lambs	5	5	5	5
Digestion coefficients, %				
Organic matter	90.4^{a}	$91.5^{a,b}$	$93.0^{a,b}$	95.2^{b}
Crude protein	83.8	79.9	80.3	84.9
Total carbohydrates	92.4^{a}	$93.8^{a,b}$	$95.0^{a,b}$	96.8^{b}
Ether extract	$76.9^{a,d}$	$82.5^{a,b,d,e}$	$87.6^{b,d,e}$	$92.0^{b,e}$
Energy	88.4^{a}	$89.6^{a,b}$	$91.2^{a,b}$	93.6^{b}
TDN content, % of dry matter	$90.8^{a,d}$	$93.5^{a,b,d,e}$	$96.6^{b,c,d,e}$	$99.5^{c,e}$
Digestible energy, Kcal/lb DM	1833^{a}	$1850^{a,b}$	$1900^{a,b}$	1945^{b}

^{a,b,c}Means with different superscript letter differs significantly ($P < .05$).

^{d,e}Means with different superscript letter differs significantly ($P < .01$).

Table 6. Comparisons of Dry and Ensiled High Moisture Corn Grain.

Item	Moisture content	Daily gain, lb	Dry matter/100 lb gain, lb
Less than 29% moisture in high moisture corn - 20 comparisons			
Dry	12.6	2.53	618
Ensiled	25.8	2.57	583
Change due to ensiling	----	1.6%	-5.3%
More than 29% moisture in high moisture corn - 10 comparisons			
Dry	13.7	2.62	814
Ensiled	31.0	2.46	797
Change due to ensiling	----	-6.1%	-2.1%

Table 7. Influence of Moisture Content on the Fermentation of Corn Grain (Goodrich *et al.*, 1975).

Item	Initial moisture content, %		
	21.5	27.5	33.1
No. of lab. silos	8	8	8
Dry matter ensiled, g	2251	2071	170^{b}
Dry matter loss, %	2.7^{a}	3.7^{a}	5.6^{b}
Energy loss, %	1.9_{d}	$2.7_{d,e}$	3.6_{e}
pH	5.90^{a}_{d}	$5.32^{a,b}_{e}$	4.82^{b}_{e}
Gas production, l/kg DM ensiled	1.44^{a}	4.07^{b}	4.96^{c}
Organic acid and ethanol contents, uM/g DM ensiled			
Acetic acid	11.3^{a}_{d}	$19.6^{a,b}_{e}$	23.1^{b}_{e}
Propionic acid	1.9	3.6	3.6
Butyric acid	1.1^{a}_{d}	$4.5^{a,b}_{d}$	16.9^{b}_{e}
Lactic acid	30^{a}	204^{b}	180^{b}
Ethanol	147^{a}	275^{b}	310^{c}
Organic acid and ethanol contents, % of DM			
Acetic acid	0.07	0.12	0.14
Propionic acid	0.01	0.03	0.03
Butyric acid	0.01	0.04	0.15
Lactic acid	0.27	1.84	1.62
Ethanol	0.71	1.32	1.49

[a,b,c] Values within a row with different superscript letters differ significantly ($P<.01$).

[d,e] Values within a row with different subscript letters differ significantly ($P<.05$).

UTILIZATION BY RUMINANTS OF STARCH FROM HIGH MOISTURE GRAINS - PROBLEMS AND POTENTIALS

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Grain use in North American feedlots accounts for much of the disappearance of this commodity (Waldo, 1973). In many parts of the land, it is more efficient to harvest the grain wet and either ensile the grain or treat it with acid to prevent spoilage. Alternatively, it has been found that reconstitution of some dry grains with water improves their utilization. This review analyses metabolic effects of feeding high moisture grains to ruminants. Some of the current problems and potentials as this writer sees it are set out.

Performance data for beef cattle fed high moisture grains have recently been reviewed (Baker, 1973; Clark, 1975; Hale, 1973; Jones et al.,1974; and Rutledge, 1971). Out of 17 studies comparing dry with high moisture corn, high moisture outperformed or equalled dry in eleven (Clark, 1975). Of the six for which high moisture was inferior to dry, a superior response in feed efficiency was obtained for high moisture corn in five. Most of the differences however between these two grain processes for corn are small and not statistically significant. The reader should also be cautioned that some of the superiority in feed efficiency attributed to high moisture grain may be due to artifactually deflated dry matter values ascribed to the wet grain (Goodrich and Meiske, 1971). Some of the variable response for high moisture grain may relate to whether the corn was fed whole or broken. In Ontario, we recommend feeding high moisture corn rolled when substantial amounts of roughage are included in the diet. For all or high-concentrate diets, the corn may be fed whole (Macleod et al., 1976).

It would be extremely difficult to account for the inferior gain responses in the six trials recorded by Clark (1975). Storage plays a most important role. Nevertheless, it is interesting to note that of the six inferior studies, moisture content of the high moisture corn exceeded 30% in four and was 29.2% in another. In only three out of the 11 superior studies did corn moisture exceed 30%.

Baker (1973) reviewed performance data comparing high moisture and dry sorghum grain in ten trials from Arizona, Texas and Oklahoma. In these trials, the dry sorghum was rolled or ground. Grains were marginally improved by feeding high moisture grain but feed efficiency was markedly improved (10-20%). Superiority for high moisture (reconstituted) grain over steam rolled dry sorghum is more controversial. In contrast to shelled corn, optimum results for high moisture sorghum are obtained at a moisture level of about 30% (Baker, 1973).

It is worthwhile reviewing the mechanism whereby additional moisture enhances utilization. Water penetration of the grain kernel disrupts the aleurone protein layer and releases starch granules contained inside. It is not clear if this is a biological process or simply a facilitation of physical disruption when the kernel is ground by machine or mastication. Additionally, water penetration may cause embryonic development which in turn causes the aleurone layer to secrete an enzyme which liquifies the starch (Baker, 1973). In either case increased protein solubility likely accompanies improvement in the availability of the starch. It has been proposed that acid treatment of corn may cause hydrolysis of starch thereby facilitating digestion (Baker, 1973). Gelatinization of the starch and other chemical changes are clearly not involved when the wet grain maintains a low temperature (McNeill et al., 1975). These aspects have been researched and studied (French, 1973; Sullins et al., 1971).

Conditions, under which water penetration into sorghum and in vitro dry matter digestibility of sorghum are improved, have been studied (Florence et al., 1968; Neuhaus and Totusek, 1971). For most benefit, whole grain sorghum, rather than the rolled or ground grain should be treated with water to bring the moisture content to approximately 30%. Greatest improvement comes within a few days of water treatment but improvement does continue thereafter. A temperature of at least 16^{o}C is desirable and some benefit to higher temperatures than that have been observed (Neuhaus and Totusek, 1971). Superimposed upon these factors is the significance of grain variety (McGinty and Riggs, 1968; Sandstedt et al., 1968 and Waldo, 1973). Caution in comparing grain treatments should be exercised since some of the results may be explained simply by differences in particle size.

To evaluate the mechanism whereby additional water affects grain, it might be important to know more about differences between reconstituted grains and the same grain ensiled as high moisture. Fermentation tends to be restricted when the grain is reconstituted (Goodrich et al., 1975). Tonroy et al. (1974) observed that improvements in feed utilization were almost doubled in comparing ensiled high moisture against dry corn versus reconstituted against dry corn. In contrast, Riggs and McGinty (1970) have found high moisture, early harvested sorghum to be equal to reconstituted sorghum in feed value.

In vivo digestibility data for high moisture and dry corn and sorghum grain have been reviewed and are presented in Tables 1 and 2 respectively. With the exception of the studies by Clark and co-workers, all the corn data are for high or all-concentrate diets. Although differences are statistically significant in only two out of the eight studies, digestibility of at least one of the high moisture corn diets exceeded the corresponding dry corn diet in all but one. These results are supported by data from two other studies not included in this table (Adeebe et al., 1971; McLaren and Matsushima, 1968). This relationship is borne out by the energy and starch data also (Table 1). It is clear that any improvement in digestibility for high moisture over dry corn is quite small. Improvements in protein digestibility for high moisture corn may be directly related to dry matter but may also be a specific result of disruption of the aleurone layer and proteolysis causing more soluble protein (McKnight et al., 1973). Galyean et al. (1975) found that protein digestibilities were less for high moisture versus dry corn but the differences were not statistically significant. The data are too limited to conclude any differences between acid-treated and reconstituted versus untreated high moisture corn.

The sorghum data are more clear cut with statistically significant improvements in digestibility of dry matter, energy or starch for reconstituted versus dry groung grain occurring in four out of the five comparisons involving cattle. In the fifth, there was an improvement but it was not statistically significant. A species difference is evident, in which it appears sheep can digest dry ground sorghum grain better than cattle (Buchanan-Smith et al., 1968). Using sheep to evaluate high moisture grains for extrapolation of results to cattle may be inappropriate.

Although differences in digestibility favouring high moisture versus dry grain do exist, they are variable and small, particularly in the case of corn. Further examination of the utilization of these grains is required. Partitioning of digestion in the ruminant whereby enzymatic degradation of starch in the intestine is increased at the expense of bacterial degradation in the rumen is considered important for several reasons. Three comparisons between dry and high moisture grain with respect to preintestinal digestibility are shown in Table 3. It is evident that more, rather than less, dry matter and starch are digested in the rumen when corn is fed as high moisture versus dry. Acid treatment appears to depress ruminal digestion perhaps through protection of breakdown of the grain protein in the rumen (Atwal et al., 1974). The reasons for a greater ruminal fermentation of dry matter or starch from high moisture grains may relate to a decreased rate of passage from the rumen. McKnight et al. (1973) reported rates of liquid flow out of the rumen (1/h) in steers fed dry, acid-treated and high-moisture ground diets of 4.7, 3.55 and 3.9. Differences between high-moisture and dry grains were statistically significant ($P<.05$). The dry corn was comparable to the acid treated corns with respect to particle size but was finer than the high moisture ground corn (McKnight et al., 1973). Increased passage of dry corn directly to the intestines may not benefit utilization since the capacity of the small intestine to digest raw starch to form glucose may be limited (see Mayes and Ørskov, 1974).

Patterns of volatile fatty acid formation in the rumen favouring propionate are considered beneficial for the efficiency of feed utilization. In several in vivo and in vitro studies, it has been reported that the molar proportion of propionate is unaffected when finely ground dry corn or sorghum is compared with the corresponding high moisture grain (Franks et al., 1972; Helm et al., 1972; Lane et al., 1972; McKnight et al., 1973 and Tonroy and Perry, 1974). In one study, the acetate:propionate ratio decreased but this was explained by a reduction in acetate and a corresponding compensation by an increasing proportion of butyrate (Helm et al., 1972). If high moisture grains were to be better utilized than dry grains by digestion favouring propionate production or glucose producation in the small intestine, then it is most probable that metabolic heat production would decrease. From complete energy balance studies, this does not appear to be the case (Kiesling et al., 1973). Improvement in net energy for high moisture over dry grains appears to be largely the result of improved digestibility.

The following are some factors to consider, from the digestive and metabolic point of view, in order to maximize the efficiency of utilization of high moisture grains:

1. Impact of soluble nitrogen.

Although the energy from high moisture corn appears to be efficiently utilized, it is probably dependent upon there being an adequate supply of amino acids available at the absorption sites. High levels of soluble nitrogen in forage diets have been shown to adversely affect gain of heifers (Waldo et al., 1973). The requirement for supplemental rumen bypass protein may be greater in the case of feeding high moisture than dry grain. This is due to high soluble nitrogen levels in high moisture corn although levels may be insignificant under some conditions.

2. Supplementation with other nutrients.

Precaution is required to supplement high moisture grains with other essential nutrients besides energy and protein since Young et al. (1975) have reported extensive deterioration of vitamin E in high moisture corn storage.

3. Significance of rate of passage from the rumen and rumen turnover.

Decreases in these criteria might account for improvement in digestibilities upon feeding high moisture grain but they may also be associated with depressing output of microbial protein relative to organic matter digested in the rumen (Cole et al., 1975). This could depress the amino acid supply of the animal further. Means of enhancing rumen turnover by increased saliva secretion through appropriate roughage inclusion (Bauman et al. 1971) or characteristics of the mineral are worth investigation. Rumen turnover should not increase to the point that the capacity for starch hydrolysis in the small intestine is exceeded or digestibility of starch decreases. In this regard, results of Wheeler et al. (1976), suggesting that intestinal degradation of starch is associated with higher pH in the reticulo-rumen, abomasum and throughout the intestine, are of interest. It would also be interesting to know to what extent decreased rumen turnover is responsible for the decreases observed in dry matter intake when high moisture versus dry grain is fed to ruminants.

Effects of roughage source and level upon utilization of grain have been studied and the results are of interest. Ahmed et al. (1973) reported that feeding silage versus hay in an acid-treated high moisture barley diet depressed intake. Clark and Harshbarger (1972) reported that the digestibility of a dairy ration using corn in the concentration mixture was depressed when corn silage rather than hay was the source of roughage. Waldo (1973) concluded that ruminal digestion of starch from diets containing raw corn was 75, 72, 66 and 75% when corn was included to levels of 20, 40, 60 and 80%, respectively. Minimal fermentation of corn occurred in a 52% corn diet.

CONCLUSIONS

Cattle generally perform as well or better on a high or all-concentrate diet containing high-moisture grain than they do on a diet based on dry grain. It is likely that this is partially due to favourable effects upon digestibility. There is however variation in response to feeding high moisture grains and room for improvement. Research investigations should concentrate on basic factors which are characteristic of high moisture grain feeding. These revolve around three areas: namely, soluble nitrogen, erosion of essential nutrients in high moisture grain that occurs during storage and low rumen turnover or flow rate.

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Table 1. Comparisons between high moisture and dry corn on whole tract digestibilities in ruminants.

	Moisture Content	Type of diet and level of feeding*	Species	Dry matter	Energy	Starch	Crude Protein	References
Dry grnd	14.1	66%	Bovine,	74.7[a]	72.9[a]	92.3[a]	64.5	McKnight et al.,
Acid-treated, grnd	20.8	corn,	320 kg.	76.9[b]	74.8[a,b]	94.6[b]	66.9	1973
Acid-treated, grnd	22.6	1.5M		77.7[b]	75.9[b]	95.9[b]	68.5	
High moisture, grnd	22.8			76.4[b]	74.5[a,b]	92.8[a]	66.9	
Dry rolled	11.2	78%	Bovine,	79.9		96.3[a]	68.4	Galyean et al.,
Acid-treated whole	19.9	corn,	430 kg.	78.5		95.8[a]	66.0	1975
High moisture grnd	25.3	1.0M		80.4		99.1[b]	66.7	
Steam flaked	17.0			80.4		99.1[b]	66.0	
Dry grnd	13.1	60% corn	Bovine,	83.5[+]				McCaffree and
High moisture grnd	28.1	(approx.)	245 kg.	89.8				Merrill, 1968
Dry,grnd and Hay	13.3	Complete	Bovine,	66.9[a]			66.4	Clark and Har-
Dry,grnd and Silage	13.3	feed,	lactating	63.8[a]			63.2	shbarge, 1972
High moisture, grnd and Hay	29.9	3.0M	cow	69.8[b]			68.5	
High moisture, grnd and Silage	29.9			67.5[b]			66.7	
Dry, grnd	11.8	Complete	Bovine, lac-	64.4			67.4[a]	Clark et al.,
Acid-treated, grnd	19.0	feed,3.0M	tating cow	59.7			62.3[b]	1973
Dry, whole	11.3	70%	Bovine	79.5	78.6		69.4[a]	Tonroy et al.,
High moisture, whole	29.0	corn,	200 kg.	80.7	80.0		74.5[b]	1974
Reconstituted, whole	26.2	2.0M		80.6	80.1		73.0[a,b]	
Acid-treated, whole	26.3			79.9	79.0		70.0[a]	

Table 1 Con't.

	Moisture Content	Type of diet and level of feeding*	Species	Dry matter	Energy	Starch	Crude Protein	References
Dry, rolled	12.3	83% corn,	Ovine,	78.2	76.6	90.0	60.4	White et al.,
High moisture, rolled	29.8	1.5M	45.7 kg.	79.9	78.8	99.2	63.5	1973
Reconstituted, rolled	25.6			79.4	78.5	98.8	62.4	
Acid-treated, rolled	24.9			77.6	76.6	98.4	60.1	
Dry, whole	13.2	92% corn	Bovine,	84.0	82.5		73.3	Macleod et al.,
High moisture, whole	29.0	2.0M	275 kg.	82.0	80.7		71.4	1976
High moisture, rolled	29.0			84.8	83.6		74.2	

[*] 1.0 M infers that feeding level was approximately one times maintenance.

[a,b] Values in same trial bearing different superscripts differ, P<.05.

† TDN, estimated for concentrate corn-soybean meal mixture, level of feeding not reported.

Table 2. Comparisons between high moisture and dry sorghum for whole tract digestibilities in ruminants.

	Moisture Content	Type of diet and level of feeding*	Species	Dry Matter	Energy	Starch	Crude Protein	References
Dry grnd	---	83%	Bovine			96.8^{a}		McNeil et al.,
Reconstituted grnd	30.0	sorghum,	370 kg.			99.5^{b}		1971
Steam flaked	---	1.0M				99.7^{b}		
Micronized	---					97.1^{a}		
Dry rolled	---	84% sorghum,	Bovine		73.6^{a}			Kiesling et
Reconstituted rolled	38.0	1-2M	300 kg.		80.0^{b}			al., 1973
Dry rolled	---	84% sorghum,	Bovine		73.1			
Reconstituted rolled	38.0	1-2M	430 kg.		76.6			
Dry grnd	17.0	60%	Ovine,	74.2	72.9		65.6	Harpster et al.
Acid treated grnd	27.2	sorghum,	40 kg.	70.7	70.4		63.4	1975
High moisture grnd	32.0	1-5M		70.6	69.9		60.0	
Dry grnd	10.3	99.9%	Bovine,	64.4^{a}			44.5^{a}	McGinty et al.,
Reconstituted grnd	29.7	sorghum, 1.0M	ylg.	83.1^{b}			51.7^{b}	1967
Dry grnd	12.3	78.3%		75.7^{a}	73.7^{a}	91.9	64.7	Buchanan-Smith
Steam flaked	15.8	sorghum, 1.5-	Bovine,	$79.9^{a,b}$	$78.2^{a,b}$	94.3	65.6	et al., 1968
Reconstituted rolled	30.0	1.75M	350 kg.	81.6^{b}	79.5^{b}	94.6	71.0	
Dry grnd	12.3	78.3%	Ovine,	80.4	79.5	92.8	71.6^{a}	Buchanan-Smith
Steam flaked	15.8	sorghum, 1.5-	30 kg.	79.8	79.0	93.7	66.8^{b}	et al., 1968
Reconstituted rolled	30.0	1.75M		81.7	80.6	93.0	73.2^{a}	

* 1.0M infers feeding level was approximately one times maintenance.

a,b, Values in same trial bearing different superscripts differ.

Table 3. Comparisons between dry and high moisture corn and sorghum diets for pre-intestinal digestion in ruminants.

	Moisture Content	Percent grain in diet and level of feeding*	Species	Digested prior to intestines: Dry Matter	Digested prior to intestines: Starch	References
Dry, grnd	14.1	66% corn, 1.5M	Bovine, 320 kg.	25.2[a]	47.3	McKnight et al., 1971
Acid-treated, grnd	20.8			44.5[a,b]	75.7	
Acid-treated, grnd	22.6			37.4[a,b]	63.0	
High moisture, grnd	22.8			54.2[b]	81.4	
Dry, rolled	11.2	78% corn, 1.0M	Bovine, 430 kg.		77.8[a]	Galyean et al., 1975
Acid-treated, whole	19.9				62.8[c]	
High-moisture, grnd	25.3				89.3[b]	
Steam flaked	17.0				82.9[a,b]	
Dry, grnd	--	83% Sorghum, 1.0M	Bovine, 370 kg.		42.0[a]	McNeill et al., 1971
Reconstituted, grnd	30.0				66.7[b]	
Steam flaked	--				83.4[c]	
Micronized	--				43.0[a]	

* 1.0M infers feeding level was approximately one times maintenance.

a,b,c Values in same trial bearing different superscripts differ.

Utilization of nitrogen from fermented feeds

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It is now well recognized that during the ensiling of chopped whole plant material or grain, a number of chemical (compositional) changes occur that can modify the nutritional value of the stored feeds. The two major changes during the ensiling-storage period are the solubilization of protein (macromolecular) nitrogen and the fermentation of soluble carbohydrates to lactic acid. In chopped whole plant silages, the nitrogen solubilization process occurs during the first few days of the ensiling period and appears to be a consequence of the activity of endogenous plant proteases (Bergen *et al.*, 1974). In stored high moisture grain (corn) the solubilization process is slower and not quite as extensive; the mechanism for N solubilization in high moisture corn has not been identified (Prigge *et al.*, 1976).

Bergen *et al.* (1974) observed that the soluble nitrogen fraction of corn silage was not able to support an adequate rate of *in vitro* cellulose digestion (Table 1). More recent work has shown that soluble nitrogen isolated in bulk from corn silage was not readily degraded to NH_3-N in the rumen of sheep.

These results have focused attention on the nutritional quality of this N fraction in fermented ensiled feeds. For an effective rumen fermentation of dietary carbohydrates, there must be an adequate NH_3-N source to promote microbial growth and activity. If a sizeable fraction of the nitrogen in feeds can not be degraded (or converted) to NH_3-N, then there will be a depression in the extent of digestion in the rumen with a concomittant depression in animal performance.

Table 1. *In vitro* cellulose digestion by ruminal microorganisms in the presence of different nitrogen sources.

N Source	Rate of Digestion (12 hr.)	Extent of Digestion (48 hr.)
	----------- %	-------------
Urea	44	60
Corn Silage - Soluble N	23	55

To date it is not clear to what extent the solubilized nitrogen can be utilized *in vivo*. Further there is very little information on the utilization of the insoluble nitrogen in ensiled or high moisture feeds. The limit of biological availability of nitrogen from ensiled or high moisture feeds must be determined to insure adequate formulation of rations for livestock (ie. any discounting of ensiled feed protein must be made up by including more supplemental N; either as NPN or preformed protein).

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ENSILING CONDITIONS AND SOLUBLE NITROGEN AND HIGH MOISTURE CORN UTILIZATION

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Common methods of high moisture grain storage include grinding and packing into up-right or pit silos or storing the grain in the whole form in air tight silos or by treatment with organic acid. Major difference exists in the solubility of the protein or nitrogen fractions of these grains depending on storage method. Sprague and Breniman (1969) have related high levels of soluble nitrogen to poor performance in feedlot cattle. Studies conducted at Oklahoma and elsewhere indicate that the solublization of nitrogen occurring during the storage of high moisture corn can be related to positive performance aspects, such as increased efficiency of energy and perhaps protein utilization as well as some of the negative aspects such as liver abscesses, sudden death syndrome and irregular consumption patterns.

In this report, the relationship between soluble nitrogen and ration utilization will be discussed. As well as some of the **elements which contribute** to the degradation of protein during ensiling. A greater knowledge of these factors must be obtained to establish more definite guide lines for the storage and feeding of high moisture corn in order to obtain maximum animal performance with minimum risk.

Factors Affecting the Soluble Nitrogen

Observation from work conducted at Oklahoma (Prigge et. al. 1974) indicate that several factors are involved in the degree of soluble nitrogen in high moisture corn.

Major difference in nitrogen solubility exist when the grain is stored whole as opposed to ground. The results reported in Table 1 indicate that at 56 days ensiling, 38% of the nitrogen was in the soluble form for the ground whole shelled corn as opposed to 15% for the nonground. It is also indicated in Table 1 that an increase in soluble nitrogen (SN) occurred at 56 days storage. Determinations of lactic and acetic acid levels from these samples indicated that bacterial fermentation was completed at 21 days ensiling, thus nitrogen solubility appeared to be independent of bacterial fermentation. This however is not entirely true as will be discussed later.

Laboratory samples tend to indicate that beyond 56 days increases in soluble nitrogen would be small. It should be pointed out that these samples of corn were ensiled in one liter glass jar and even when larger 55 gallon drums are used the level of soluble nitrogen usually are considerably lower than found in field samples. Up to 70% of the nitrogen in field samples has been found to be in the soluble form. The results of Table 1 indicate that over 80% of the soluble nitrogen is non-protein nitrogen. This is in agreement with feedlot samples. Field samples also indicate that course rolling the grain prior to ensiling will also tend to have lower levels of SN.

The effects of various additives on soluble nitrogen content of the corn are reported in Table 2. It is evident that neither the addition of $CaCO_3$ or chemical preservatives added prior to storage had any affect on the soluble nitrogen content in the ground corn. However, in the whole shell grain the AP treatment (a mixture of propronic and acetic acid) showed a greater soluble nitrogen content.

The pH values (Table 2) indicate a significant lower pH for this treatment. The increased acidity associated with the AP treatment of the whole shelled corn could be a factor involved in the higher SN content. Studies (Prigge et. al. 1975) suggest that the plant enzymes are responsible for changes in the nitrogen composition of high moisture corn and studies by (Burger, 1966) indicate that certain proteolythic enzymes of grain tend to have an optimal pH on the acid side. These results suggest that bacterial fermentation may be an indirect factor on the solubilization of nitrogen due to its pH effects in ground high moisture corn. It appears that time of ensiling, and particle size, up to a point and acidity all have affects on soluble nitrogen to a certain extent however, studies reported by Dr. Thorton indicate that moisture content of the grain at storage time has been shown to have the most consistant relationship with SN in field samples. It appears that exposure of corn protein to the active acidity of the surrounding fluid media may be the important element in determining the degree of soluble nitrogen.

Soluble Nitrogen and Energy Availability

Observations in the feedlot have related ground high moisture grain to increased incidence of condemned livers, sudden death syndrome and sub-clinical acidosis. All of the maladies have been associated to a certain extent to excessively low rumen pH. Studies have indicated (Johnson et. al. 1973) that rumen pH were significantly lower for ground high moisture corn than other processing methods due most likely to an increase in readily fermentable energy.

The reasons for large increases in fermentable energy during the high moisture storage of corn have not been fully understood, however, there is some evidence to associate this with increases in soluble nitrogen content of the grain. Texas workers (Florence et. al. 1968) suggest that during the storage of reconstituted sorghums, energy availability was increased due to the destruction of the proteinaceous matrix surrounding the starch granules.

Studies conducted at Oklahoma seem to indicate that a similar response might occur during the storage of high moisture corn. In vitro incubation (Galyean et. al. 1974) indicate that dry matter disappearance are well correlated with the soluble nitrogen content of high moisture corn, however, this difference disappeared when small amounts of urea were added to the incubation tubes. The results appeared to indicate that a certain amount of soluble nitrogen might be necessary for optimal dry matter digestions. However, since the levels of urea added were quite low they could easily be compensated for in vivo by recycled nitrogen into the rumen via the saliva and blood. The relationship between in vitro dry matter disappearance and soluble nitrogen will be discussed further in Dr. Thorntons report.

Energy availability was also studied by collecting CO_2 produced by incubating samples of the grain with amyloglucosidase and yeast. The results of which are reported in Table 3 and 4. In Table 3, the percentage of readily available carbohydrates appeared to increase at 12 days ensiling at 24.3% soluble nitrogen. This however, does not indicate that energy availability was maximized at this point, it must be remembered that portions of the carbohydrates which could have been contributed to the CO_2 collected were degraded to organic acids during the ensiling process. This suggests that the readily available energy of the corn could be increased inspite of lower amounts of gas produced at the later ensiling intervals.

The results of gas production studies comparing various processing methods have been studied by Galyean (1975) and are reported in Table 4, as can be observed ground high moisture corn and acid treated corn were both superior to dry corn in CO_2 produced and except for the steam flacked corn, the results generally showed a correlation with the soluble nitrogen content being 15.3, 63.6 and 11.7%, respectively for acid treated high moisture corn, ground high moisture corn and dry rolled corn.

Attempts were made to limit the degree of solubilization from ground high moisture corn by formaldehyde treatment at levels ranging from .2 to .5 percent on an as is basis. Although not entirely successful, the data as can be observed (Table 6) indicated the ruminal starch digestibilities were reduced significantly for the high moisture formaldehyde treated rations. Although the formaldehyde rations had greater amounts of starch digestion in the post-ruminally, the starch from the untreated ration was more digestible.

The results from these studies and those reported elsewhere suggest a direct relationship between soluble nitrogen and energy availability of corn rations. Although the question has not been fully resolved as to the benefits of increasing ruminal degradation of starch, studies with grains, processed by other methods have associated increased degradation of starch in the rumen with increase feed efficiency. The question (Orskov, 1969) as to the ability of ruminants to utilize starch post-ruminally is one that has to be resolved in the near future.

Soluble Nitrogen and Nitrogen Utilization

The ability of ruminants to retain proteins of high solubility has generally been reported to be inefficient. This suggests that perhaps the nitorgen in high moisture corn would not be utilized as well as that of dry corn. In addition it has been suggested that high levels of soluble nitrogen found in corn would appear to limit urea utilization (Burrough et. al. 1974).

In order to examine utilization of nitrogen from high moisture corn rations with urea (Prigge et. al. 1976), steers were fed rations containing 80% dry corn (DC) or high moisture corn (HMC) with either soybean meal (SBM) or urea (U) as supplements. Levels of soluble nitrogen for a DC-SBM, DC-U, HMC-SBM and HMC-U rations were 35, 52, 73 and 92% of the total nitrogen respectively. The results of this study indicated that the post feeding ruminal pH depressions were greater for the steers fed the HMC as opposed to the DC rations. This agreed with previous observations (Johnson et. al. 1974) and the results were as expected. Rumen ammonia concentrations were expected to correlate with the solubility of protein in the rations since intakes were isonitrogeounus (Annison et. al. 1974). However, the relationship did not apply. Rumen ammonia levels (Figure 1) were higher ($p < .05$) at 1/2 and 1 hour post feeding for the dry corn and urea containing rations with significant interactions at both times. Mean comparisons indicated that ammonia production was significantly higher for the DC-U ration than all other rations. This suggests that urea was utilized perhaps more efficiently with high moisture corn rations despite the inheritantly high levels of soluble nitrogen. If ammonia is being released in high moisture corn as one would suggest from the high soluble nitrogen levels, and does not accumulate in the ruminant. Either enhanced ammonia use by rumen bacteria or excelerated ammonia absorption occurs. Plasma urea levels (Figure 2) were greater at 1/2 and 1 hour ($p < .05$) and 2 hours ($p < .01$) for steers fed dry corn than those fed the high moisture rations suggesting greater NH_3-N absorption from the blood, for the DC rations. These data suggest that ammonia was used more extensively for microbial protein synthesis with the HMC rations.

Subsequent studies (Galyean et. al. 1975) appeared to indicate that with both acid treated high moisture corn fed whole, and ground high moisture corn, a greater proportion of the nitrogen reaching the abomasum in the form of microbial protein when compared to the dry rolled rations.

Subsequent nitrogen balance studies with lambs fed nitrogen depletion rations for several weeks prior to being placed on the experimental ration were initiated. The lambs were fed either the dry corn or high moisture corn rations with either soybean meal or urea as supplemental nitrogen as in the previous study with steers. The results of these studies are reported in Table 6. No significant difference was observed in apparant digestibility of dry matter or crude protein, although fecal nitrogen appeared to be slightly higher for the high moisture corn rations.

Urinary nitrogen was low and nitrogen retention greater for lambs fed high moisture corn. A significant interaction of corn type and nitrogen source was observed for percent of absorbed nitrogen retained, with urea being more beneficial with the high moisture corn than the dry corn based rations. The percent of absorbed nitrogen retained also indicated that protein quality was higher for the high moisture as opposed to the dry corn rations.

In this series of studies, Nitrogen appeared to be utilized more efficiently from high moisture corn rations than from dry corn rations. Studies by Potter et. al. 1969 and 1970 also tended to indicate that nitrogen in sorghum grains were utilized more efficiently when reconstituted then fed in a dry form in addition, the reconstituted grains appeared to utilize urea more efficiently than cotton seed meal. The results of these studies tend to indicate that urea can be utilized as well with high moisture corn as with dry corn rations, and suggest that the optimal animal performance can be achieved with lower amounts of supplemental nitrogen or protein than is required for dry grain ration.

Conclusion

It appears from the studies reported here that a certain percentage of soluble nitrogen is necessary for efficient energy and protein utilization. It is evident from studies reported in the literature that at least some of the disadvantages of high moisture feeding programs is that nitrogen and energy is too readily available.

Until guide lines are developed to ensure a consistant high moisture corn that will provide maximized feed efficiency and gains with a minimum of feed problems, the best results at present might be obtained by formulating rations to meet the specific needs of a particular high moisture crop based perhaps on its soluble nitrogen or other chemical determinations.

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Table 1. Influence of Storage Time and Storage Method on Soluble Nitrogen Content of High Moisture Corn.

Storage Method	Storage Time	Soluble N	Soluble NPN	Soluble Protein
	(days)		% Total N	
Ground [A]	0	15.8[a]	7.3[a]	8.5
	6	21.9[b]	15.2[b]	6.7
	12	24.3[b]	18.9[c]	5.4
	28	33.1[c]	27.2[d]	5.9
	56	38.2[d]	32.1[e]	6.1
Whole shelled[B]	0	11.3[a]	7.9[a]	3.4
	28	11.7[a]	7.6[a]	4.1
	56	14.8[b]	11.1[b]	3.7

[a,b,c,d,e] Values in columns within a storage method with different superscripts differ statistically ($P < .05$)

[A,B] Significant difference ($P < .01$) due to storage method at 28 and 56 days of storage in soluble N, soluble NPN and soluble protein contents.

Table 2. The Influence of Additives on Soluble Nitrogen Levels of High Moisture Corn

Storage Method	Storage Time	Additives	Soluble Nitrogen	pH
	(days)		%	
Ground	28	Control	29.6	4.3^{ab}
		AP[1/] (1.5%)	27.3	4.5^{ab}
		AIB[2/] (2.0%)	29.5	4.7^{b}
		$CaCO_3$ (0.5%)	28.2	4.7^{b}
Whole shelled	28	Control	11.7^{a}	6.1^{c}
		AP[1/] (1.5%)	18.2^{b}	4.6^{a}
		AIB[2/] (2.0%)	10.0^{a}	5.8^{c}
	56	Control	14.8^{a}	4.9^{b}
		AP[1/] (1.5%)	21.7^{b}	4.6^{a}
		AIB[2/] (2.0%)	14.0^{a}	5.8^{c}

[a,b,c,d] Values in a column within a storage method with different superscripts differ statistically ($P < .05$).

[1/] 80:20 propionic to acetic acid

[2/] Ammonium isobutyrate

Table 3. Ensiling Time, Soluble Nitrogen Levels and Gas Production of Ground High Moisture Corn

Days ensiled	0	2	6	12	21	28	56
Soluble Nitrogen	15.8	18.3	21.9	24.3	31.7	33.1	38.2
CO_2 produced[1/]	44.9[a]	51.0[bc]	49.0[ac]	54.0[b]	53.9[bc]	52.8[bc]	52.3[bc]

[1/] ml/gm DM

[a,b,c] Values in row which do not have the same superscript are significantly different ($P < .05$)

Table 4. *IN VITRO* GAS PRODUCTION OF PROCESSED CORN GRAIN[d]

Ration	Hour[e]						
	1	2	3	4	5	6	Total
AHMC	17.6[b]	10.3[bc]	11.3[b]	8.2	8.4	7.2	63.0[bc]
SF	32.4[a]	18.6[a]	17.1[a]	12.4	10.0	7.8	98.1[a]
GHMC	18.7[b]	10.7[b]	12.4[b]	10.2	10.3	9.4	71.5[b]
DR	16.3[b]	9.3[a]	9.5[c]	7.7	6.7	6.7	55.8[c]
SEM	2.7	0.3	0.3	0.8	0.7	0.6	3.2

[a,b,c]Means in a column which do not have the same superscript are significantly different ($P < .05$)

[d]Each mean is the average of eight observations.

[e]Values are reported as ml gas/gm dry matter.

TABLE 5. FORMALDHYDE TREATMENT OF HIGH MOISTURE CORN AND STARCH UTILIZATION

Item	Formaldhyde Level 0	.20	.50
Soluble nitrogen	16.2	4.0	2.0
Ruminal starch Digestion, %	72.2^{a}	51.2^{b}	56.3^{ab}
Post ruminal Starch digestion			
% of diet	25.5^{a}	38.1^{ab}	32.0^{ab}
% of supply	96.6^{a}	80.7^{b}	83.1^{ab}
Total starch digestion, %	97.7	89.3	88.3

[ab] Means in rows which do not have the same superscripts are significantly different ($P < .05$).

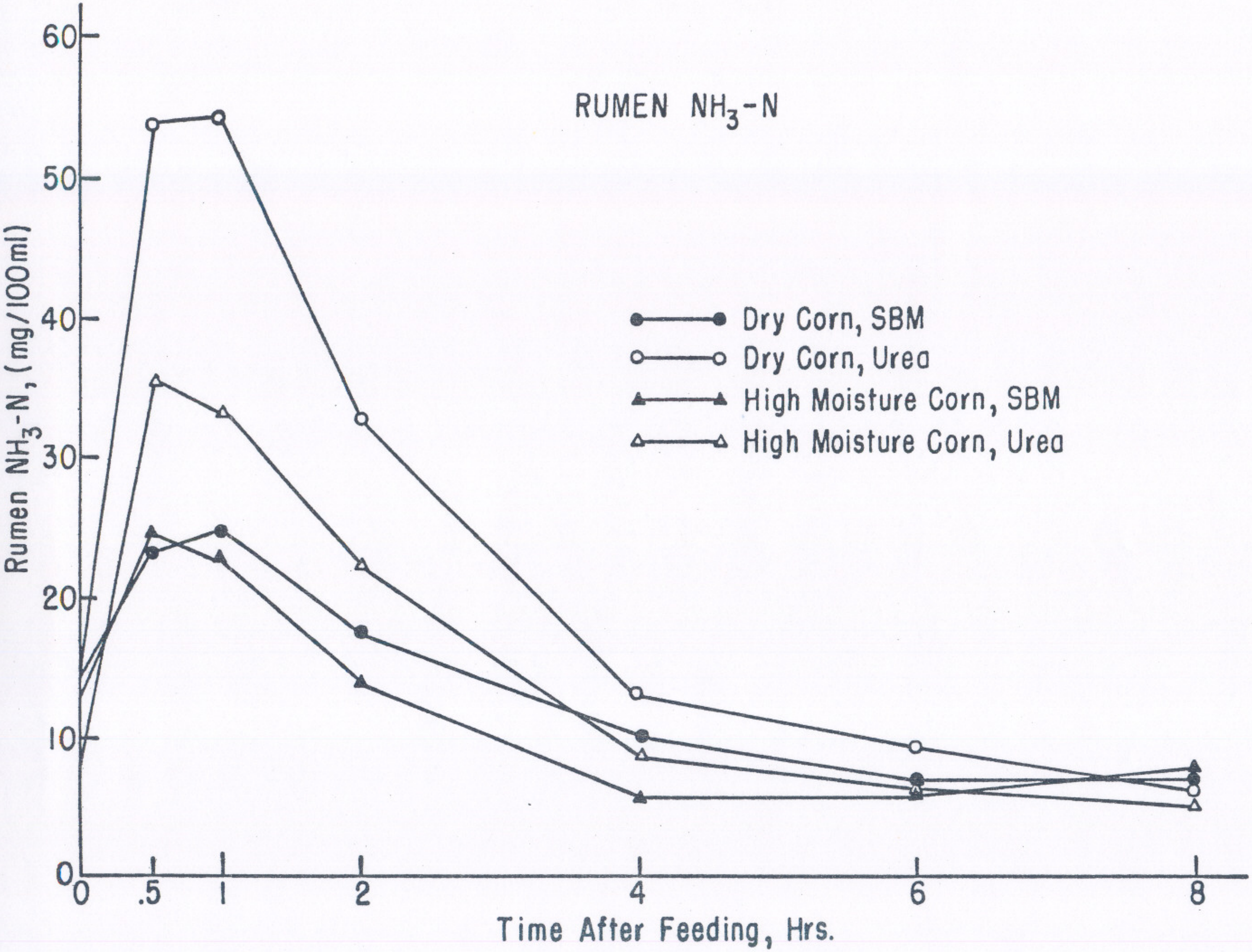

Figure 1. Rumen ammonia levels of steers fed various rations.

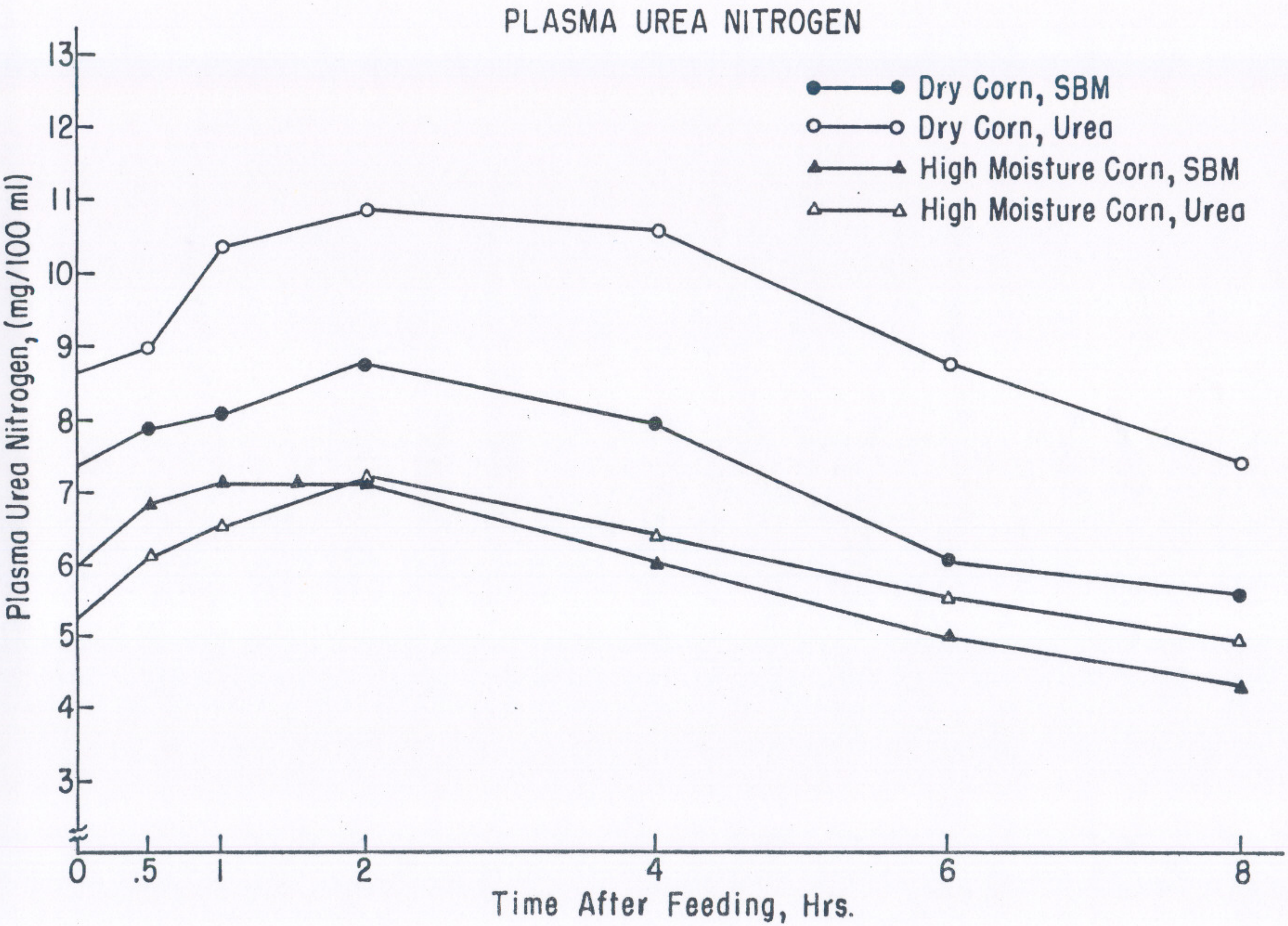

Figure 2. Plasma urea nitrogen levels of steers fed various rations.

Table 6. NITROGEN RETENTION OF DRY AND HIGH MOISTURE CORN RATIONS WITH SOYBEAN MEAL OR UREA AS SUPPLEMENTAL NITROGEN SOURCES

ITEM	DC + SMB	DC + UREA	HMC + SBM	HMC + UREA
Dry matter intake g/day, $kg^{.75}$	51.2	48.7	51.9	52.4
N, intake g/day, $kg^{.75}$	1.04	1.03	1.01	.98
Digestible dry matter, %	74.2	77.3	74.4	73.5
Digestible protein, %	66.5	68.7	62.5	62.4
Fecal H, g/day, $kg^{.75}$	.35	.32	.38	.38
Urinary N, g/day, $kg^{.75}$	$.39^{a}$	$.43^{a}$	$.30^{b}$	$.28^{b}$
N, retained, g/day, $kg^{.75}$	$.32^{a}$	$.34^{ab}$	$.35^{b}$	$.36^{b}$
N, retained/ absorbed, %	46.4^{a}	44.0^{a}	56.0^{b}	59.1^{b}

[ab] Means in a row with different superscirpt are significantly different (P .05)

RECONSTITUTED GRAIN

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Reconstituting whole grain has been used successfully to improve utilization by cattle in commercial lots for more than 12 years. This method of processing has not been as widely used as steam flaking, particularly in large lots, because of costs of storing large quantities of grain and handling problems. Increasing gas costs plus the possibility of a shut off of gas usage for boilers in feedlots has renewed interest in reconstituting grain to improve feed efficiency. Field observations and research reports indicate that reconstituting sorghum and corn does not improve feed efficiency as consistently as high moisture ensiling but is necessary in many high moisture programs because of storage capacity limitations.

Research has indicated that rate of gain on reconstituted grain is usually equal to or improved over that when dry rolled grain is fed (Table I). Feed conversion has been improved by an average of 12.7 percent when ensiled whole and ground or rolled before feeding. These performance differences support the energy values reported by Kiesling et al (1973) of 1.457 NE m+g MCal/kg dry matter for dry rolled and 1.693 for reconstituted. If ground or rolled before ensiling feed efficiency was depressed in as many trials as it was improved when compared to dry rolled or ground grain. When trench or other oxygen unlimited storage is used, grinding or rolling is necessary to prevent spoilage. In these situations high moisture harvested grain is preferred over dry reconstituted (Brethour and Duitsman. 1962)

Trials reported in Table I based feed conversion values on a dry basis when fed and did not consider dry matter loss during ensiling. Hoffman and Self (1975) reported dry matter losses of 12.5% in concrete-stave silos and 6.0% in oxygen limiting systems. They did not give corresponding dry matter loss for handling and storing dry grain but an industry average for 6 months storage would be about 3 percent. Caution should be taken in determining moisture on ensiled grains to prevent volatile nutrients from being included in the moisture entity (Hood et al. 1971).

Many factors influence the performance of reconstituted grain as compared to dry rolled or ground. The particle size of the dry rolled or ground grain (particularly sorghum) used in the comparison influences the degree of improvement that can be expected. A decrease in dry sorghum particle size improves utilization (White et al. 1969). Grinding after reconstitution produces a much smaller particle than grinding before ensiling (Table 11).

Neuhaus and Totusek (1971) reported that in vitro digestibility improvements became progressively larger at 26, 30 and 34 percent moisture for whole reconstituted grain. Reconstituting ground grain did not improve dry matter digestibility at moisture levels varying from 14 to 30 percent. Feed efficiency of sorghum reconstituted whole at 22 percent moisture was not significantly improved over dry rolled but was improved at 30 and 38 percent moisture (White and Totusek, 1969). Wagner et al. (1971) reported that 30 percent and 38 percent moisture sorghum improved feed efficiency to a similar degree and significantly better than dry rolled. Optimum moisture levels for reconstituting corn may be lower than those for sorghum. Tonroy et al. (1974) in separate trials observed greater improvement in feed efficiency at corn moisture levels of 18 and 20 percent than 25 percent.

In commercial operations an ensiling time of 3 weeks is generally recommended for reconstituting whole grain. Neuhaus and Totusek (1971) reported an increase of 6 percent in in vitro digestibility after 1 day of ensiling up to 15 percent to 32 days. Wagner et al. (1971) reported no significant difference in feed efficiency of sorghum ensiled 10 or 20 days before feeding.

The pattern of digestibility of reconstituted grains is quite different to other methods of processing. Several workers observed a significant improvement in dry matter digestibility due to reconstituting whole grain (Berry and Riggs, 1971; Buchanan-Smith et al., 1968; Riggs and McGinty, 1970; and Schake et al., 1969). The average dry matter digestibility of dry ground sorghum observed by these workers was 71.7 percent whereas an average digestibility of 80.6 percent was observed after reconstitution. An improvement in starch digestibility is the major factor contributing to improved dry matter digestibility, but these same workers also observed an improvement of protein digestibility from an average of 55.5 percent for dry ground to 65.0 percent for the reconstituted.

The influence of processing on the extent of digestibility of these nutrients ruminally and post ruminally must influence utilization to a degree not yet fully appreciated. McNeill et al. (1971) reported 23 percent more ruminal starch digestion from reconstituted sorghum than from dry rolled (Table 111). Susceptibility of the sorghum to amyloglucosidase was not significantly altered by reconstitution (Table 1V) indicating that a change in starch gelatinization is not a factor in improved ruminal digestion.

Ruminal digestion of protein is greater from reconstituted sorghum than from dry rolled, steam flaked or micronized sorghum (Table V). Buchanan-Smith et al. (1968) reported lower nitrogen retention however from reconstituted sorghum rations than from dry rolled sorghum rations. Lysine and leucine values observed by Potter et al. (1971) indicate that protein digestion of reconstituted grain and subsequent amino acid synthesis produces a higher "quality" protein at the abomasum than other methods of processing studied.

Sprague and Brenniman reported 62.5 and 64.9 percent of the total protein in 30.5 and 32.0 percent moisture reconstituted corn to be ethanol soluble. Reconstituted corn containing 24.1 percent moisture showed only 25.8 percent ethanol soluble protein (of the total protein). They related depressed performance in feedlot cattle consuming high moisture ensiled corn to low level ammonia toxicity due to high protein solubility.

Increased availability of starch and protein due to sorghum reconstitution must be partially due to a disruption of the endosperm (Sullins, et al. 1971). McNeill (1975) also observed a partial disruption of the protein matrix surrounding the starch molecule due to reconstitution.

Results of the research reviewed and on feeding observations on reconstituted grain suggest possibilities of beneficial future studies with this method of processing. Since site of digestion in the gut varies with different processing methods, a combination of two grain treatments in a ration might have an associative effect. The advent of acid treatments to preserve high moisture grain to avoid expensive storage structures should be investigated further (even though one trial by Bolsen et al., 1967 showed poor response) to determine if the method has application to reconstitution. None of the reviewed trials were conducted with Rumensin. One of the large lots in the Texas Panhandle has reported an increase in consumption and gain with the addition of Rumensin to reconstituted sorghum rations. Since ruminal fermentation of reconstituted grain differs from that of other processing, the effect of Rumensin needs to be known. Possibly the increased protein solubility of reconstituted grain will be found to be a consistent advantage instead of occasional problem with more protein utilization studies.

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TABLE 1

INFLUENCE OF RECONSTITUTING SORGHUM

AND CORN ON FEEDLOT PERFORMANCE

DAILY GAIN GROUND, ROLLED RECONSTITUTED	RECONSTITUTED GROUND, ROLLED	FEED EFFICIENCY GROUND, ROLLED RECONSTITUTED	RECONSTITUTED GROUND, ROLLED	REFERENCE
----	+0(g); 0(r)	----	+4.9(g); +14(r)	15
----	+3.8(g); +12(r)	----	+7.3(g); +16.9(r)	24
----	-2.4	----	+11.8	25
-1.8	+11.6	-3.5	+ 9.0	23
----	+0	----	+11.0	17
+16.0	+7.0	+15	+23	1
----	+8.8	----	+15.6	22
----	+7.7	----	+28.1	26
----	-5.1	----	+ 6.0	11
+1.2	+0	-5.4	- 4.3	4
-9.5	----	-11.0		3
	+5.2	+2.5		21
	-3.9	+7.7		21
	+0	+12.8		21
	+6.5	-3.4		21

TABLE 11

PARTICLE SIZE OF SORGHUM GRAIN DRY

GROUND AND GROUND BEFORE OR

AFTER RECONSTITUTION

SIEVE SIZE	DRY GROUND	GROUND BEFORE RECONSTITUTED	RECONSTITUTED BEFORE GROUND
	%	%	%
1.68 mm	11.8	15.7	2.4
0.841	41.2	43.2	16.4
0.595	17.0	16.5	11.0
0.420	8.6	10.1	7.6
0.210	9.4	8.8	13.6
0.149	9.6	3.3	22.3
0.149 /	2.2	2.3	24.6

SULLINS ET AL. 1971

TABLE 111

RUMINAL, POSTRUMINAL AND TOTAL

DIGESTION OF STARCH

	DRY GROUND	RECONSTITUTED	STEAM FLAKED	MICRONIZED
RUMINAL DIGESTION %	42.03	66.67	83.41	42.99
POSTRUMINAL DIGESTION %	94.42	98.42	98.42	95.00
TOTAL DIGESTION %	96.76	99.47	99.74	97.14

MCNEILL ET AL. 1971

TABLE IV

SUSCEPTIBILITY OF PROCESSED SORGHUM

GRAIN TO AMYLOGLUCOSIDASE

TREATMENT	MG OF GLUCOSE RELEASED/GRAM DRY MATTER
DRY GROUND	118.6[c]
RECONSTITUTED	139.3[c]
STEAM FLAKED	615.5[a]
MICRONIZED	232.7[b]

Mc NEILL ET AL. 1975

TABLE V

RUMINAL ACTION ON FEED PROTEIN

AS AFFECTED BY PROCESSING

	RUMINAL BREAKDOWN %
DRY GROUND	51.28
RECONSTITUTED	79.48
STEAM FLAKED	62.16
MICRONIZED	36.11

POTTER ET AL. 1971

TABLE VI

LYSINE AND LEUCINE PATTERNS IN

ABOMASOL FLUID HYDROLYSATES FROM

STEERS FED PROCESSED SORGHUM GRAIN (MOLAR%)

	LYSINE	LEUCINE
DRY GROUND	5.30[bc]	9.49[ab]
RECONSTITUTED	6.20[a]	8.33[c]
STEAM FLAKED	5.61[ab]	8.88[bc]
MICRONIZED	4.62[c]	9.81[a]
RATION HYDROLYSATES	2.37	12.39
BACTERIAL PROTEIN[b]	6.50	7.00

POTTER ET AL. 1971
LITTLE ET AL. 1965[b]

STABILITY AND BUNK LIFE OF HIGH MOISTURE CORN

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Dry matter and energy losses which occur from the faces of silage (1) prior to unloading from silos and (2) following unloading but prior to being consumed by livestock are referred to as after-fermentation. Silages with low rates of after-fermentation are said to be stable, and thus, have a relatively long bunk life. After-fermentation in silages is caused by aerobic organisms becoming active because of the presence of oxygen prior to or following unloading from silos. The aerobic organisms metabolize residual carbohydrates and lactic acid in silage and the heating of feeds after unloading is indication of activity of such organisms.

In conventional tower silos, after-fermentation losses can occur from the face of the silage. In "sealed" or oxygen-limiting structures similar losses can occur in the unloading zone due to oxygen exposure during feeding periods. In horizontal silos, similar types of losses can occur from the face of the silo as well as the top surface if silos are not covered well.

Research by Zimmer et al. (1973) indicated that after-fermentation losses were primarily but not exclusively related to yeast populations and activity. Their findings suggested that yeast populations increased in silage during periods of oxygen exposure with high population being related to greater exposure. Exposure to oxygen caused by slow filling rates and improper silo construction, maintenance or management would permit aerobic microbial populations to increase. At unloading, the greater the yeast and other aerobic microbial populations, the shorter the bunk life and the greater the dry matter losses observed from silages.

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With this general background, the following discussion will review some of the research which has been conducted on the stability of (1) ensiled high moisture corn, (2) acid treated corn, and (3) unensiled high moisture corn (eg. ground high moisture ear corn from corn cribs). Results from studies with other types of high moisture feeds will be used to illustrate some ideas. Some parts of the discussion will be somewhat speculative becuase of the limited amount of research on feed stability and bunk life.

Essentially all organisms involved in feed deterioration and spoilage are aerobic organisms. Since most high moisture feeds provide excellent materials for such organisms to thrive on, it is imperative that feedstuffs such as high moisture corn (HMC) be managed in a manner to minimize exposure to oxygen and thus minimize the activity of the destructive organisms. Some of the findings of Zimmer et al. (1973) have been discussed. An extensive study using high moisture barley in conventional tower silos under farm conditions was conducted by Lacey (1971) and his findings confirmed the studies in Germany and showed the complexity of the microbial populations involved in feed deterioration. Lacey (1971) found that with an unloading rate of 7.5 cm/day (3 in/day) or more, only yeasts were abundant. As unloading rates became slightly slower molds (Penicillium spp.) also became common. As unloading rates decreased further the above organisms became less abundant and a series of other mold species became prominent. Under very slow unloading and extensive heating, thermophilic fungi were most prominent. Our visual observations and limited amount of microbial examinations on several types of silage at the University of Guelph would appear to agree with the observations of Lacey. Our findings indicate that the dry matter losses which occur from good quality HMC during the first few hours after unloading from well managed silos are largely due to yeast activity. A much wider spectrum of organisms become active under situations of extended exposure before feeding or under slow unloading conditions.

In most regions of North America, researchers and extension specialists recommend that high moisture shelled corn (HMSC) be processed through some type of grinder, roller, hammer-mill or forage harvester with a recutter screen prior to ensiling. Of course, high moisture ear corn (HMEC) must be processed prior to ensiling. It is generally assumed that the smaller particle size of the processed HMC would consolidate better than whole kernels, and thus, reduced oxygen penetration and energy losses would occur. One might assume that the bunk life of the processed HMC would also be superior to the HMSC. Zimmer et al. (1973) (translated and shown by Stevenson (1975)) found that processed corn stored in gas tight silos was more stable (had lower losses) than did whole HMSC stored under similar conditions. However, there was no difference in stability between ground and whole ensiled kernels which had been stored in conventional silos. In studies recently completed at Guelph, ensiled whole HMSC consistently had slower heating and lower dry matter losses than did the same material in the ground form (Table 1). Both types of HMSC were stored in laboratory silos (2 moisture contents and 4 replications) and dry matter losses were determined using the system reported by Stevenson and Stone (1974). It can be seen from Table 1 when HMC of any type is stored properly and fed within 24 hours that very small after-fermentation losses will occur. If however, ensiled corn is exposed for a few days, for example on the face of an excessively wide horizontal silo or a conventional silo with a very slow feeding rate, then losses can be significant.

Stevenson (1975) reported results of preliminary trials on HMC of various types from three types of tower silos. In all but one case, losses in the first 24 hours after unloading were small with the most stable sample losing 0.1% DM. The least stable sample came from an oxygen limiting silo in which the bottom hatch had been opened periodically for 3 days prior to sampling. The HMSC from this silo had started to heat in the silo and when removed losses were significant with valves of 2.7% DM and 25.5% after 12 and 120 h, respectively.

From our laboratory and farm silo studies described above it is clear that HMC that is stored under well managed conditions has a low population of aerobic organisms at the time of unloading. If fed within 24 h, losses are minimal because populations of yeast and other aerobic organisms do not have time to develop. Where extended exposure to oxygen is permitted, either in silos, feed bunks or feed storage areas, microbial populations and activity increase to significant levels and dry matter losses and heating become serious.

Stevenson (1974) reported results of a study on the bunk life of whole-plant corn silage from three farm silos. Corn silage from a well managed silo had essentially no dry matter loss in the first 24 h following unloading and lost only 1% DM after 70 h. Corn silage from another farm which was in the early stages of heating in the silo because of inadequate unloading rate lost 1% DM in only 20 h after unloading. Obviously, aerobic microbial populations were becoming active while in the silo resulting in significant losses both prior to and following unloading. Corn silage from a third silo was the worst quality silage and the poorest management that this author has seen. The silage was severely caramelized and the losses during storage were so great that only the pericarps of the corn kernels were remaining. Losses following unloading were very small probably because essentially no substrate remained for microbes to metabolize. Thus, a stable silage is usually but not always a good quality silage.

The method of unloading silos is also known to affect stability and dry matter losses prior to and following removal of silage from silos. Research in Germany indicated that unloaders for horizontal silos which left a smooth, straight, well packed face produced more stable silage with lower losses than did power loaders which tended to loosen and fragment the face of the silage.

Treatment of HMC with organic acids has received considerable publicity in the past few years. When properly treated, acid treated corn has essentially no dry matter losses during or following storage. It is as stable as dry grain at feeding time.

Acid treated grain can be mixed with dry grain in mixed rations and the resulting ration will have a bunk life of at least several days and often weeks before serious feed deterioration occurs.

Propionic acid or propionic-acetic mixtures appear to have some potential as silage additives. It is known that sub-sterilization rates of propionic acid reduces heating in hay crop silage and extends the bunk life of the treated silage. In research at Guelph sub-sterilization rates (0.2% of ChemStor) on 30% m HMC reduced heating in the early stages of ensiling of the HMC. The low rates of application inhibit aerobic organisms but allows lactobacilli to function and a fermentation similar to that of untreated silage occurs. We have not yet conducted experiments to determine if low rates of ChemStor (or any other comparable product) will extend the bunk life of ensiled HMC.

The bunk life of many fresh crop commodities is even shorter than ensiled material. For example, ear corn stored in corn cribs can heat rapidly upon grinding if the moisture content of the material in excess of 25% m and ambient temperatures are above 10 C. Rapid heating results from both cellular respiration in the corn as well as microbial activity. Microbial activity develops rapidly on fresh processed high moisture crop products because adequate soluble substrate is usually available and the pH being near neutrality is ideal for microbial development. An experiment was recently conducted at Guelph comparing the effects of three additives on the dry matter loss of 30% m ground HMEC (Table 2). The following additives were studied:

1) 0.4% ChemStor (8 lb /ton)
2) Urea (20 lb/ton)
3) Siloguard (2 lb/ton)
4) Untreated control

ChemStor was the most effective additive for minimizing feed losses, reducing feed deterioration and extending bunk life. It appears that even lower rates could be used when short term storage is required. Certainly low rates of organic acids appears to have significant potential in extending the storage life or bunk life of perishable feeds. The difference in dry matter losses between the control and the ChemStor treatment were great enough to pay for the ChemStor by the end of the third day. Urea was also effective by the end of the first day when ammonia levels became sufficiently high (0.45% of DM) to inhibit further microbial activity.

SUMMARY:

Most of the heating which occurs in the ensiling process is the result of aerobic reactions, either plant respiration or microbial activity. It can be shown by mathematical calculations or laboratory experiments with instrumented insulated silos, that the trapped air in silage contains only a small amount of oxygen. Trapped oxygen in most silage would permit less than a 5 C temperature rise. Therefore, significant heating and excessive dry matter losses in silage must result from surface exposure during filling of silos or from air entering the silage mass during storage. It is important to minimize exposure of silage to oxygen to avoid excessive losses and heating.

In addition, excessive exposure to oxygen during storage or prior to and following unloading permit the development of high populations of yeast and other aerobic microbes. The activity of these microbes result in feed deterioration and loss and shorten the bunk life of the feed. Under conditions of good silo management, 1) rapid filling, 2) sealing silos when not being used, 3) feeding rates in the order of 7.5 cm/day in warm weather or 5.0 cm/day under cold conditions, losses are small from ensiled HMC and bunk life is relatively long.

Organic acids inhibit the activity of aerobic microbes and thus extend the bunk life of feeds. The greater the rate of application the greater the storage life or bunk life of the high moisture grain.

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Table 1. Dry matter losses as affected by moisture content, processing and time after removal from silos.

Time After Removal (h)	Dry Matter Loss (% of DM)			
	Whole HMSC		GROUND HMSC	
	72% DM	70% DM	72% DM	70%DM
20	0.1	0.1	0.2	0.3
40	0.2	0.3	0.5	0.9
80	0.5	1.0	2.0	3.5
120	0.6	2.0	4.3	7.0

Table 2. The effects of additives on dry matter losses from ground HMEC at 70% DM.

Time after Treatment (days)	Dry Matter Loss 9% of DM)			
	Control	ChemStor	Urea	Siloguard
1	1.0	0	1.4	1.4
2	2.1	0	1.7	2.8
4	4.7	0	2.2	6.0
9	9.3	0.3	3.0	11.2

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Table 1. Dry matter losses as affected by moisture content, processing and time after removal from silos.

Time After Removal (h)	Dry Matter Loss (% of DM)			
	Whole HMSC		GROUND HMSC	
	72% DM	70% DM	72% DM	70%DM
20	0.1	0.1	0.2	0.3
40	0.2	0.3	0.5	0.9
80	0.5	1.0	2.0	3.5
120	0.6	2.0	4.3	7.0

Table 2. The effects of additives on dry matter losses from ground HMEC at 70% DM.

Time after Treatment (days)	Dry Matter Loss 9% of DM)			
	Control	ChemStor	Urea	Siloguard
1	1.0	0	1.4	1.4
2	2.1	0	1.7	2.8
4	4.7	0	2.2	6.0
9	9.3	0.3	3.0	11.2

THE FEEDING VALUE OF HIGH MOISTURE GRAINS FOR BEEF CATTLE

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It is not the purpose of this discussion to present an in-depth literature review on the subject of high moisture grains for beef cattle. The literature abounds with data on research conducted with ensiled high moisture grains. The discussant of this subject reviewed nearly 50 separate articles on the subject matter of high moisture corn for beef cattle, over 50 articles on high moisture sorghum grain for beef cattle, and a smaller number of papers on high moisture barley. An execllent literature review on the total subject was prepared by Merrill[a/] for an International Silage Research Conference. Rather, it is the purpose of this discussion to summarize the literature and from such summaries to make recommendations for cattle feeders.

1. Nature of preservation of high moisture grains. Much of the discussion of this conference has dealt with the mechanics and chemistry of high moisture grain preservation. Basically, then, the storage of high moisture grains is dependent upon either anaerobic fermentation or the prevention of mold formation by the use of such materials as organic acids. The matter of choosing which technique to employ is a matter of which fits best into a given system of cattle feeding and/or which is most economical.

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Merrill, W.G. 1971. The place of silage in production rations - Feeding high moisture grain silages. Proc. 1971 International Silage Conference, Washington D.C. P. 156.

2. Advantages and disadvantages of high moisture grains. One of the real advantages of high moisture grain systems of feeding is that the harvest may be initiated two to three weeks ahead of that normally possible for harvesting grain which is to be artificially dried and stored in bins - the exception being barley. An equally large advantage to such programs is that expensive artificial drying is not necessary. Perhaps the greatest drawback to the high moisture grain system is that such grain cannot be sold in commercial channels once it has been stored as ensiled high moisture grain. However, acid treated high moisture grains may be dired to an acceptable moisture levels and subsequently introduced into commercial trade.

3. Evaluating the economic feeding value of grain systems. The most common criteria for evaluating the nutritional value of feedstuffs for livestock is (a) rate of gain, and (b) efficiency of dry matter conversion. Research reports also usually include daily feed intake, but this measurement really tells very little since the earliest indication of the efficacy of one of our newest feed additives (monensin) is the levels of appetite depression exerted by it. Therefore, within acceptable levels of daily gain, the most important factor in evaluating feedstuffs is the efficiency of feed conversion to gain.

4. High moisture ear corn. The earliest reported data on the feeding value of ensiled high moisture ground ear corn was that from Purdue University in 1958[a] in which it was reported such feed had from 12 to 15 percent greater feeding value, per unit of dry matter, based on comparable gains and decreased dry matter intake. The literature is in fairly close agreement on the subject. Unfortunately, the ear picker was pretty much replaced at about that time with the picker-sheller combine which dropped the cob on the ground behind the combine.

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Beeson, W.M. and T.W. Perry, 1958. The comparative feeding value of high moisture corn and low moisture corn with different feed additives for fattening beef cattle. J. Anim. Sci. 17:368.

Naturally, there are isolated instances in the literature which show no nutritional advantage of ensiled high moisture ground ear corn over dry ground ear corn. For example, Iowa[a/] (1958) reported no effect on efficiency of feed conversion and an eight percent slower rate of gain on ensiled high moisture ground ear corn. However, as indicated above, most researchers report an improvement in efficiency of feed conversion through the utilization of ensiled high moisture (32% water) ground ear corn.

5. High moisture shelled corn. If one were to pull out isolated research reports on high moisture shelled corn and make conclusions therefrom, almost any conclusion desired, could be made. However, under rather ideal conditions of feeding, daily gain is comparable to that of cattle fed lower moisture shelled corn; feed efficiency is almost always improved at least five percent and oftentimes, as much as 10 percent, with a range of from six to 10 percent improvement being one which cattle feeders might anticipate routinely. Therefore, on this basis, a ton of dry matter from high moisture shelled corn (25-28% H_2O) is worth nearly as much as a metric ton (2200 lb) of dry matter from "air dry" corn (15% H_2O).

6. Factors affecting the feeding value of high moisture corn. A closer look at the vast array of research data on the subject of high moisture and the apparent discrepancy among certain data permits certain relationships and interrelationships to emerge. Some of these are especially critical to the cattle feeder and should be considered.

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Burroughs, W., W.R. Woods, C.E. Culbertson and John Greig. 1959. Enzyme additions to beef cattle fattening rations containing low-moisture and high moisture corn. Iowa State College Ani. Husb. Leaflet 245.

a. Moisture content of the corn. Burroughs et al. (1971)[a] summarized the data from 17 comparisons involving different moisture levels of corn stored in sealed storage. An average improved feeding value of 10 percent for high moisture ear corn showed a low of plus seven percent when the corn had from 23 to 32 percent moisture and a high of 13 percent for moisture levels of 33 to 44 percent (there was one high level of 23 percent improvement for 44 percent moisture corn in the higher moisture group). The higher moisture levels may give some harvesting problems and a realistic optimum for high moisture ear corn is from 30 to 35 percent moisture.

For high moisture shelled corn, the average improved feeding value of six percent was partitioned into seven percent for moisture levels of 23 to 27 percent and five percent for 28 to 35 percent moisture levels. The recommended moisture level for high moisture shelled corn is 25 to 30 percent.

b. Reconstituted vs. original moisture corn. The feeding results from "reconstituted" (dry corn treated with water to bring the moisture level to 25 to 30 percent) corn has been quite erratic. Generally, in the case of corn, it is recommended that original moisture high moisture corn will give more consistent benefits than "reconstituted" high moisture corn.

c. Level of roughage in the diet. Embry[b/] presented data to show that rolled high moisture shelled corn has more advantage over rolled dry corn when fed with corn silage than when fed in an all-concentrate diet. With corn silage, rolled high moisture shelled corn produced equal or greater gains, had greater feed efficiency, whereas in all-concentrate diets, all comparative data were nearly the same for both types

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a/ Burroughs, W., H.L. Self and M.R. Geasler. 1971. Iowa cattle feeding trials with high moisture corn. Grain Feeders Seminar, Iowa State Univ.

b/ Embry, L.B. 1971. Grain processing for feedlot cattle. 7th Annual Oklahoma Cattle Feeders Seminar.

of corn. When hay represented about 65 percent of daily dry matter, high moisture shelled corn increased gain eight percent and improved feed efficiency seven percent; with haylage at 65 percent of daily dry matter, rolled high moisture shelled corn resulted in 12 percent faster gains and 10 percent less feed per pound gain than for rolled dry corn.

d. Organic acid preserved high moisture corn. It has been concluded generally by research data on the subject that cattle respond to high moisture shelled corn treated with organic acids as they do ensiled high moisture shelled corn.

7. High moisture sorghum grain. Since milo is the basic energy grain of the sprawling cattle feeding industry of the Southwest, it is appropriate that Texas, Oklahoma and Kansas have conducted the majority of the research concerned with the nutritive value of high moisture sorghum grains for beef cattle.

The benefits from high moisture sorghum grain over comparable dry sorghum is much more dramatic than it is for corn. Their feeding value in the dry form is lower than their chemical composition would predict. Basic research into this discrepancy indicates the starch of dry sorghum grain is less available and the protein is not utilized as well as that of corn or barley. Therefore, almost anything that can be done to sorghum grain probably will improve its nutritive value for livestock.

Cattle fed ground moist sorghum grain have required less grain dry matter per pound of gain than did those fed ground dry grain, ranging from 15 to 20 percent with an overall average of 20 percent. In practically all comparisons high moisture sorghum grains have resulted in a lowered feed intake compared to other processing methods such as steam flaked or ground or rolled dry grain. With similar weight gains, then, feed efficiency is increased.

Further processing of high moisture sorghum grain is important. For example, beef cattle fed ground high moisture sorghum grain gained 11 percent faster and required 37 percent less grain dry matter per unit of gain than cattle fed the same high moisture grain in whole form. Rolling either high moisture grain sorghum or dry sorghum is superior to fine grinding, for increasing efficiency of feed conversion.

The change that takes place in reconstituting grain sorghum, some have felt, is similar to that which occurs during germination in which the starch of the endosperm is liquified to an extent for use by the growing seedling.

8. Whole vs. processed grain for reconstitution. For sorghum grain ensiled with its original high moisture, ensiling either whole or crushed is equally effective in improving its feeding value over that of dry grain. Reconstituting whole grain, which was then processed prior to feeding has given equal or greater improved daily gains and improvement in feed efficiency, compared to ground dry sorghum grain. However, grinding grain sorghum prior to reconstituting has not been satisfactory, resulting in slightly lower rates of gain and poorer feed efficiency.

9. Optimum moisture level for sorghum grain. The ideal average moisture content for high moisture sorghum grain is 30 percent, with a range of 25 to 35 percent. Similarly, the ideal reconstituted level is 30 percent moisture. However, its most difficult to add more than ten points of water from the starting point.

It is critical in the reconstituting of sorghum grain that the grain remain in the reconstituting process a minimum of time. That minimum appears to be approximately 21 days.

10. Why increased value of high moisture sorghum grain? Increased dry matter digestibility has been proposed as the primary factor causing increased feed efficiency from using high moisture sorghum grain. It has been shown, for example, reconstituted sorghum grain has an increase of digestibility of dry matter, organic matter and non-protein organic matter of a magnitude of from 12 to 29 percent.

11. High moisture barley. Barley kernels are physiologically mature when the moisture content drops below 40 percent. The ideal average moisture content for high moisture barley is 30 percent, similar to that for high moisture sorghum grain.

All the physical advantages related to earlier harvesting for barley add to the increased feeding value of high moisture barley. Research indicates that high moisture barley has a place in cattle feeding - but not because of increased gain nor because of improved feed efficiency. The chief advantage of high moisture barley appears to be its high acceptability, with cattle going on feed faster, resulting in better early gains. Cattle stay on feed easier on high moisture barley than do those on dry rolled barley.

High moisture barley should be rolled for beef cattle. In comparative studies, cattle fed whole high moisture barley gained .3 lb less per day and required 63 pounds more feed per 100 lb gain than cattle whose high moisture barley was rolled prior to feeding.

DAIRY PRODUCTION USING HIGH-MOISTURE CORN

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Reduced field, harvesting, and storage losses, earlier harvesting, and adaptation to mechanical feeding are factors which have contributed to increased use of high-moisture grains. Field drying, artificial drying and ensiling high-moisture grain are the most common methods of preserving grains for livestock feeding. Reports (3, 7, 8, 12, 15, 22, 24, 26) also indicate that spraying high-moisture grain with organic acids in direct proportion to their moisture content results in excellent preservation of grain. Thus, drying, ensiling or organic acid treatment of high-moisture grain are effective means of preserving grain for livestock feeding. Various aspects of high-moisture grain storage and feeding have been reviewed in earlier publications (26, 37, 49). This review will supplement and update previous reviews concerning the utilization of high-moisture grain by dairy animals. No attempt is made to cite all published research in this area but instead to provide a good representation of the research findings. Only results of research conducted with grains harvested as the high-moisture product will be included in the review.

Dry Matter Intake from High-Moisture Grains by Dairy Cattle

Generally, diets containing ensiled (6, 7, 8, 13, 14, 21, 24, 27, 28 30, 33, 51) or organic acid treated (7, 8, 12, 19, 20, 23, 24, 29, 32) high-moisture grains have been found to be highly palatable to lactating cows (Table 1). The high dry matter intakes of such feeds by dairy cows suggest good preservation of grain using these methods of preservation. In some studies, feeding high-moisture grain also has been shown to decrease total dry matter intake (9, 27, 34, 35, 37, 40, 41). In these experiments, it has been suggested that the decrease in total dry matter intake of diets containing high-moisture grain is due to a decrease in forage intake (9, 34, 35, 37). However, the latter suggestion has not been tested systematically with varying concentrate to forage ratios in which high-moisture grain was fed and dry matter intake was measured in the same experiment. The major factor restricting intake of high-moisture grain is improper use of storage methods resulting in a damaged and a poor quality feed. High-moisture grain must be treated in such a way to prevent mold growth because such contamination lowers the nutritive value and the acceptability of the grain by animals. In addition, mycotoxins produced by certain molds present a potential health hazard to both humans and animals (31).

Effect of High-Moisture Grain Feeding on Milk Production

Feeding ensiled or organic acid treated, high-moisture grain to lactating cows has generally resulted in acceptable milk yields (Table 1). Clark and Harshbarger (9) indicated that cows fed diets containing high-moisture shelled corn performed equally well as cows fed dry shelled corn. Feeding a combination of high-moisture, shelled corn and hay resulted in a greater milk yield compared to feeding high-moisture, shelled corn and corn silage. In later work by Clark et al. (8) it was shown that milk yield was not significantly different between cows fed diets containing dry corn, ensiled high-moisture shelled corn or acid treated high-moisture shelled corn along with either hay or haylage. Chandler et al. (6) also have reported no significant difference in milk yield between cows fed either dry, shelled corn or ensiled, high-moisture, shelled corn. Data of Jones (24, 25) and Forsyth et al. (12) suggest similar lactation performance from dairy cows fed either dry, shelled corn or organic acid, treated high-

Table 1. Dry matter intake, milk yield, milk fat percentage and efficiency of feed utilization by dairy cows fed high-moisture grain or dry grain

of grain in diet	No. of cows per treatment	Length of trial	Moisture content of grain	Dry matter intake: Concentrate	Forage	Total	Milk yield	Fat	kg FCM per kg D.M. intake	Ref. No.
		days	%	kg/day			kg/day	%		
shelled corn	20	105	13.4	8.9	10.0[a]	18.9[a]	25.8	3.24	1.19[a]	
led shelled corn	20	105	29.9	8.8	9.0[b]	17.7[b]	26.5	3.21	1.30[b]	9
shelled corn	20	112	14.0	8.0	10.4	18.4	23.8	3.50	1.23	
led shelled corn	20	112	24.2	8.0	11.0	19.0	25.0	3.58	1.21	
ionic acid shelled corn	10	112	23.7	8.0	10.5	18.5	24.0	3.71	1.22	8
shelled corn	12	84	11.8	7.5	10.7	18.2	21.8	3.61[a]	1.13	
ionic acid shelled corn	12	84	19.0	7.3	10.4	17.7	20.9	3.82[b]	1.14	8
shelled corn	16	77	12.2	5.8	10.9	16.8	16.9	3.78	.96	
led shelled corn	16	77	25.3	6.2	10.9	17.0	17.7	3.77	1.00	
ionic acid shelled corn	16	77	22.1	6.2	10.9	17.1	17.4	3.80	.98	7
shelled corn	16	112	11.2	7.2	13.0	20.1	21.4	3.78	1.03	
led shelled corn	16	112	24.2	7.1	12.6	19.7	21.3	3.70	1.04	
ionic acid shelled corn	16	112	26.5	7.1	12.6	19.7	21.2	3.74	1.04	7
shelled corn	8	154	----	10.7[a]	7.2	17.9	31.9	2.18[a]	1.30	
led shelled corn	8	154	28.8	9.8[b]	8.2	18.0	30.1	2.74[b]	1.34	6
shelled corn	6	80	----	10.1	7.2	17.3	32.8	2.34	1.42	
led shelled corn	6	66	28.8	9.1	6.2	15.3	31.5	2.97	1.75	6
shelled corn	6	207	----	10.2	6.8	17.0	24.9	2.81[a]	1.20	
led shelled corn	6	207	28.8	9.6	8.9	18.5	24.0	3.37[b]	1.17	6

Cont. Table 1.

of grain in diet	No. of cows per treatment	Length of trial	Moisture content of grain	Dry matter intake: Concentrate	Dry matter intake: Forage	Dry matter intake: Total	Milk yield	Fat	kg FCM per kg D.M. intake	Ref. No.
		days	%	kg/day			kg/day	%		
helled corn	10	81	----	8.7	7.6	16.3	15.4	3.08	.82	
ed shelled corn	11	85	28.8	8.7	8.3	17.0	15.8	3.26	.83	6
ar corn	6	305	----	----	----	----	24.6	3.87	----	
helled corn	6	305	----	----	----	----	22.8	3.85	----	
onic acid shelled corn	6	305	33.5	----	----	----	23.1	3.97	----	23
airy supplement	12	84	10.6	7.2	13.2	20.4	17.5	4.10	.87	
onic acid shelled corn	12	84	33.3	6.0	12.1	18.1	17.6	3.90	.96	
ed shelled corn	12	84	34.7	6.5	12.1	18.6	17.4	4.20	.96	24
helled corn	12	98	13.0	3.4	10.7	14.1	15.9	3.60	1.05	
onic acid shelled corn	12	98	30.0	2.9	10.8	13.8	16.3	3.50	1.08	12
helled corn	14	42	13.0	8.3	11.4	19.7	26.7	3.64	1.28	
onic acid shelled corn	14	42	19.1	7.8	11.0	18.8	25.5	3.32	1.22	
c and propionic acid elled corn	14	42	20.0	8.3	9.9	18.2	27.5	3.39	1.37	32
helled corn	12	112	----	9.0	7.2[a]	16.2[a]	26.1	3.56[a]	1.51	
ed shelled corn	12	112	31.1	9.5	5.3[b]	14.8[b]	27.5	3.02[b]	1.59	34
ed shelled corn	8	112	29.6	9.8	7.4[a]	17.2	30.0	3.51	1.62	
ed ear corn	8	112	39.5	9.7	8.8[b]	18.4	30.8	3.49	1.55	34
helled corn	6	84	14.0	6.2	12.0	18.2	22.7	3.74	1.20	
ed shelled corn	6	84	35.0	6.4	12.3	18.7	23.0	3.59	1.16	14

Cont. Table 1.

e of grain in diet	No. of cows per treatment	Length of trial	Moisture content of grain	Dry matter intake: Concentrate	Dry matter intake: Forage	Dry matter intake: Total	Milk yield	Fat	kg FCM per kg D.M. intake	Ref. No.
		days	%	kg/day			kg/day	%		
shelled corn	6	91	13.0	5.8	11.5	17.3	21.6	3.94	1.24	
iled shelled corn	6	91	32.0	5.4	10.8	16.2	19.4	3.66	1.13	
iled ear corn	6	91	37.0	6.3	11.7	18.0	20.7	4.03	1.15	14
concentrate	8	140	----	12.6	7.9[a]	20.5	31.2	3.50	1.41	
iled ear corn	11	140	38.0	12.9	6.9[b]	19.8	32.5	3.50	1.52	35
shelled corn	4	56	11.7	5.7	12.1	17.8[a]	16.1	3.70	.87	
led shelled corn	4	56	32.0	4.9	10.8	15.7[b]	15.8	3.40	.92	
led ear corn	4	56	38.9	5.5	10.9	16.4[a,b]	15.7	3.50	.88	27
shelled corn	4	56	15.2	5.6	10.7	16.3	18.8[a]	3.40	1.06	
ear corn	4	56	17.9	5.7	12.2	17.9	20.2[b]	3.50	1.05	
led shelled corn	4	56	35.4	5.5	10.5	16.0	18.3[a]	3.20	1.01	
led ear corn	4	56	41.8	4.9	11.9	16.8	18.0[a]	3.40	.97	27
concentrate	20	112	----	4.0	11.8	15.8	21.5	3.90	1.34	
led ear corn	20	112	37.5	3.2	11.8	15.0	21.6	3.90	1.42	28
concentrate	20	154	----	3.0	13.9	16.9	18.4	4.10	1.11	
led ear corn	20	154	37.5	2.6	14.0	16.6	18.0	4.10	1.10	28
concentrate	20	84	----	4.4	11.5	15.9	20.2	2.91	1.06	
led ear corn	20	84	31.8	4.0	11.4	15.4	19.9	3.06	1.11	28
shelled corn	3	112	17.0	3.0	----	----	13.3	3.80	----	
led shelled corn	3	112	39.5	3.1	----	----	12.2	3.80	----	
led shelled corn	3	112	26.4	3.2	----	----	13.5	4.00	----	
led ear corn	3	112	34.2	3.3	----	----	12.7	3.80	----	30

Cont. Table 1.

ᴐf grain in diet	No. of cows per treatment	Length of trial	Moisture content of grain	Dry matter intake Concentrate	Forage	Total	Milk yield	Fat	kg FCM per kg D.M. intake	Ref. No.
		days	%	kg/day			kg/day	%		
ıelled corn	7	90	15.0	4.5	----	----	16.4	3.70	----	
ɘd ground shelled corn	7	90	30.8	4.8	----	----	15.3	3.90	----	
ɘd whole shelled corn	7	56	30.8	4.6	----	----	15.3	4.00	----	
ɘd ear corn	7	90	31.0	4.7	----	----	16.1	3.90	----	30
ıelled corn	15	182	----	----	----	17.7	25.5[a]	3.78	1.40	
ɘd shelled corn	15	182	----	----	----	17.4	23.8[a,b]	3.78	1.32	
: and propionic acid ɘlled corn	15	182	----	----	----	17.2	22.2[b]	3.89	1.27	20
ıelled corn	6	28	----	----	----	16.1[a]	22.4	3.96[a]	1.39	
ɘd shelled corn	6	49	35.0	----	----	13.4[b]	22.9	3.33[b]	1.54	40
ɑrley	12	35	----	11.3	7.4[a,b]	18.7	23.3[a]	3.37	1.11	
ɔnic and acetic acid y barley	12	35	----	11.2	7.5[a]	18.7	22.8[a,b]	3.53	1.13	
: and propionic acid rley	12	35	26.0	11.1	6.9[a,b]	18.0	21.8[b]	3.49	1.10	
ɘd barley	12	35	26.0	10.9	6.8[b]	17.7	22.1[a,b]	3.53	1.15	19
ɑrley	12	90	12.1	9.1	10.0	19.1	22.3	3.63	1.11	
ɘd barley	12	90	28.7	9.0	10.1	19.1	23.0	3.71	1.16	33

ɑns for a given variable within each trial not having a common superscript differ significantly ($P < .05$).

moisture corn. In contrast to these results other reports suggest that compared to dry corn, ensiled, high-moisture, shelled corn (40, 41) and acid treated, high-moisture shelled corn (20) results in lower milk production.

Milk yield of cows fed diets containing high-moisture grain, preserved several different ways, are shown in Table 1 along with the milk yield of cows fed a control diet. In summarizing the data in Table 1, a weighted mean for daily milk yield was calculated. These data are presented in Table 2 and show that the mean yield of milk for cows fed ensiled shelled corn was identical to the yield of milk for cows fed the control diet (22.2 kg/day/cow). However, cows fed dry shelled corn produced 2.3 and 5.0% more milk than cows fed either propionic acid or acetic plus propionic acid treated high-moisture corn. Feeding ensiled high-moisture, shelled corn resulted in a 3.9% higher milk yield compared to feeding propionic acid treated high-moisture corn but resulted in a 2.6% lower milk yield compared to feeding ensiled high-moisture ear corn. Milk production was 1.4% higher for ensiled high-moisture ear corn compared to dry shelled corn. Differences in the above comparisons are rather small being 5% or less. The largest difference for any of the comparisons was a 10.9% increase in milk yield when dry ear corn was compared to ensiled ear corn; however, this difference was not statistically significant. The larger differences (5 to 11%) observed in some studies may be attributable to the small number of animals used in making the comparisons. In general, these data suggest that corn properly preserved by any of the above methods will support normal milk production when fed on an equal dry matter basis. Results also show that high-moisture barley preserved properly is equal to dry barley on a dry matter basis in supplying nutrients for milk production (19, 33).

Effect of High-Moisture Grain Feeding on Milk Fat Percentage

Generally the feeding of either ensiled or organic acid treated high-

Table 2. Comparison of milk yield from cows fed high-moisture or dry corn[a]

Comparison	No. of cows	Weighted[b] milk yield	Improvement compared to control
		kg/day	%
Dry shelled corn	187	22.2	
Ensiled shelled corn	188	22.2	0.0
Dry shelled corn	90	21.5	
Propionic acid shelled corn	80	21.0	-2.3
Dry shelled corn	29	26.1	
Acetic and propionic acid shelled corn	29	24.8	-5.0
Ensiled shelled corn	82	20.3	
Propionic acid shelled corn	72	19.5	-3.9
Ensiled shelled corn	35	19.3	
Ensiled ear corn	35	19.8	2.6
Dry shelled corn	77	21.1	
Ensiled ear corn	80	21.4	1.4
Dry ear corn	4	20.2	
Ensiled shelled corn	4	18.3	-10.4
Dry ear corn	6	24.6	
Propionic acid shelled corn	6	23.1	-6.1
Propionic acid shelled corn	14	25.5	
Acetic and propionic acid shelled corn	14	27.5	7.3
Dry ear corn	4	20.2	
Ensiled ear corn	4	18.0	-10.9
Ensiled shelled corn	15	23.8	
Acetic and propionic acid shelled corn	15	22.2	-6.7

[a]Means were calculated from data presented in Table 1 and are weighted for the number of animals used on each treatment.

[b]Weighted milk yield = No. of cows for each treatment in each trial x average milk yield for each treatment in each trial/total no. of cows for each treatment.

moisture grains does not cause a depression in milk fat percentage compared to feeding dry grains (7, 9, 12, 14, 19, 20, 21, 23, 24, 27, 28, 30, 32, 33, 35, see Table 1). However, in some studies feeding high-moisture corn has been reported to cause a depression in milk fat percentage (34, 40, 41). Using the data presented in Table 1, comparisons between weighted treatment means were evaluated as was done for milk yield (Table 3). Differences between the weighted treatment means for milk fat percentages were approximately 2% when more than 14 cows per treatment were used in making the comparison. Even when small numbers of cows were used in the comparisons, the maximum depression in milk fat percentage was only 9%. It is difficult to associate the feeding of high-moisture corn with milk fat depression when all data are evaluated.

The fiber content and physical form of the diet can influence milk fat percentage dramatically. Cows consuming large quantities of concentrates, either from dry or high-moisture grain, and limited amounts of forage may produce milk containing 50 to 60% less fat than cows eating a typical diet containing adequate forage. A reduced intake of forage or more specifically fiber has been associated with studies in which high-moisture corn has caused a milk fat depression (34, 40, 41). Therefore, it is logical in view of current knowledge of milk fat depression (10) to suggest that a lowered fiber intake is the cause of decreased milk fat tests in these studies. Chandler et al. (6) compared the feeding value of dry shelled corn to ensiled high-moisture shelled corn for lactating cows and observed a .5% increase in milk fat test when high-moisture corn was fed. Adjusting for differences in dietary fiber intake resulted in nonsignificant differences between treatments with respect to fat test. Clark and Harshbarger (9) and Chandler et al. (6) concluded that high-moisture shelled corn does not cause a depression in milk fat percentage when a balanced diet containing adequate fiber is consumed by lactating cows.

Table 3. Comparison of fat percentage of milk produced by cows fed high-moisture or dry corn[a]

Comparison	No. of cows	Weighted[b] milk fat	Improvement compared to control
		%	%
Dry shelled corn	187	3.51	
Ensiled shelled corn	188	3.53	0.6
Dry shelled corn	108	3.71	
Propionic acid shelled corn	98	3.70	-0.3
Dry shelled corn	29	3.71	
Acetic and propionic acid shelled corn	29	3.65	-1.6
Ensiled shelled corn	64	3.77	
Propionic acid shelled corn	54	3.79	0.5
Ensiled shelled corn	38	3.73	
Ensiled ear corn	38	3.77	1.1
Dry shelled corn	92	3.65	
Ensiled ear corn	95	3.69	1.1
Dry ear corn	4	3.50	
Ensiled shelled corn	4	3.20	-8.6
Dry ear corn	6	3.87	
Propionic acid shelled corn	6	3.97	2.5
Propionic acid shelled corn	14	3.32	
Acetic and propionic acid shelled corn	14	3.39	2.1
Dry ear corn	4	3.50	
Ensiled ear corn	4	3.40	-2.9
Ensiled shelled corn	15	3.78	
Acetic and propionic acid shelled corn	15	3.89	2.9

[a]Means were calculated from data presented in Table 1 and are weighted for the number of animals used on each treatment.

[b]Weighted milk fat % = No. of cows for each treatment in each trial x average milk fat % for each treatment in each trial/total no. of cows for each treatment.

Alternations in rumen fermentation resulting in an increased molar percent propionic acid and a decreased molar percent acetic acid are associated with the low-fat milk syndrome. Volatile fatty acid patterns in rumen fluid have not been significantly altered when ensiled, high moisture, grains were fed unless forage intake was reduced (Table 4). Palmquist and Conrad (41) indicated a significantly reduced acetate to propionate ratio in rumen fluid of lactating cows fed high-moisture corn compared to dry corn. Forage intake by the cows receiving the high-moisture corn was decreased and, thus, may account for the changes in rumen fluid volatile fatty acid patterns.

Forsyth et al. (12) suggested that feeding large quantities of high-moisture corn, treated with propionic acid, may cause a significant reduction in milk fat percentage since Rook et al. (42) observed a depression in milk fat percentage when propionic acid was infused into the rumen. The molar ratio of rumen fluid acetate to propionate has been shown to decrease slightly in some studies (8, 19, see Table 4) when acid treated grain was fed as compared to dry or ensiled grain. However, a milk fat depression was not observed during these studies. Cows producing 25 to 30 kg of milk would normally consume approximately 8 kg of dry matter per day from corn containing 30% moisture. If this corn was treated with 1.5% propionic acid (wet weight basis) and all of the propionic acid applied to the corn at harvest was consumed by the cows, then each cow would consume about 2.0 moles of propionic acid per day. Bauman et al. (2) reported that cows fed a typical forage to concentrate diet produced 13.3 moles of propionic acid per day from normal rumen fermentation. Therefore, the propionate entering the rumen each day from acid treated corn would contribute about 15% of the quantity of acid that was produced in the rumen. Although Rook et al. (42) observed a reduction in milk fat percentage when propionic acid was intraruminally infused, the amount infused was much larger than would likely be consumed from acid treated corn. It also

Table 4. Molar concentration of volatile fatty acids in rumen fluid of cows fed high-moisture or dry grains

of grain in diet	No. of animals per treatment	Moisture content of grain	Acetic acid	Propionic acid	Isobutyric acid	Butyric acid	Isovaleric acid	Valeric acid	Acetate to propionate ratio	Ref. no.
		%	Molar %							
shelled corn	20	13.4	65.2	24.9		11.0			2.46	
led shelled corn	20	29.1	64.9	23.8		11.4			2.42	9
shelled corn	20	14.0	69.8[a]	19.0[a]		11.2			3.69[a]	
led shelled corn	20	24.2	69.1[a]	19.0[a]		11.9			3.70[a]	
ionic acid shelled corn	10	23.7	67.4[b]	21.0[b]		11.6			3.23[b]	8
ear corn	4	11.7	64.9	17.2	1.7	12.7	1.7	2.0	3.77	
led shelled corn	4	32.0	64.1	16.7	1.8	13.8	2.0	1.8	3.84	
led ear corn	4	38.9	64.4	16.8	1.8	12.7	2.0	2.0	3.83	27
barley	12	15.0	55.8	26.9	1.1	13.1	1.6	1.6	2.07	
ionic and acetic acid y barley	12	15.0	58.2	24.2	0.9	14.0	1.2	1.4	2.41	
led barley	12	26.0	60.6	19.6	0.9	15.9	1.5	1.4	3.09	
ic and propionic acid rley	12	26.0	59.8	22.3	0.9	14.5	1.3	1.3	2.68	19

eans for a given variable within each trial not bearing a common superscript differ significantly ($P < .05$).

should be noted that the molar percentage shift in the rumen fluid volatile fatty acids (decreased acetate, increase propionate) may be a symptom of the low-fat milk syndrome rather than its cause (10).

High-Moisture Grain for Growing Dairy Heifers

Several reports indicate that high-moisture corn is equal in feeding value to dry corn for growing heifers. Schmutz et al. (43) reported no significant differences in weight gains in three of four studies with growing dairy heifers when ensiled ground ear corn, containing 24 to 45% moisture, was oompared to ground dry ear corn. Jones et al. (24) also reported gains of from 0.5 to 0.7 kg per day when Holstein heifers were fed a diet consisting of 4.5 kg of either acid treated or ensiled high-moisture corn, 0.45 kg of 32% protein supplement and corn silage ad libitum. There were no significant differences in gains between heifers fed the ensiled corn versus the acid treated corn. In contrast, Hansen et al. (13) reported slightly depressed weight gains with growing heifers fed a diet containing ensiled high-moisture corn compared to heifers receiving dry corn. The fact that the high-moisture corn was fed without grinding may have influenced the results. Harshbarger (14) in a later study reported that heifers fed ground ensiled corn gained faster than heifers fed whole kernel ensiled corn.

Efficiency of Utilization of High-Moisture Grain by Dairy Cattle

Although overall results indicate that feeding high-moisture grains does not significantly increase milk yield or body weight gain of dairy heifers compared to dry corn, feed efficiency has been reported in some dairy and beef feeding trials to be slightly higher for the high-moisture product. A comparison of weighted means from data presented in Table 1 indicate that feeding ensiled corn resulted in a 1 to 8% improvement in efficiency of production of 4% fat-corrected milk (Table 5). The largest improvement between dry and high-moisture corn occurred when ensiled ear corn was compared to dry ear corn. Feeding the

Table 5. Comparison of efficiency of feed utilization by dairy cows fed high-moisture or dry corn[a]

Comparison	No. of animals	Weighted[b] kg FCM per kg D.M. intake	Improvement compared to control
			%
Dry shelled corn	167	1.17	
Ensiled shelled corn	168	1.20	-2.5
Dry shelled corn	102	1.09	
Propionic acid shelled corn	92	1.08	0.9
Dry shelled corn	29	1.34	
Acetic and propionic acid shelled corn	29	1.32	1.5
Ensiled shelled corn	64	1.07	
Propionic acid shelled corn	54	1.04	2.8
Ensiled shelled corn	18	1.30	
Ensiled ear corn	18	1.27	2.3
Dry shelled corn	82	1.18	
Ensiled ear corn	85	1.22	-3.4
Dry ear corn	4	1.05	
Ensiled shelled corn	4	1.01	3.8
Propionic acid shelled corn	14	1.22	
Acetic and propionic acid shelled corn	14	1.37	-10.9
Dry ear corn	4	1.05	
Ensiled ear corn	4	.97	7.6
Ensiled shelled corn	15	1.32	
Acetic and propionic acid shelled corn	15	1.27	3.8

[a]Means were calculated from data presented in Table 1 and are weighted for the number of animals used on each treatment.

[b]Weighted feed efficiency = No. of cows for each treatment in each trial x average kg 4% FCM per kg dry matter intake for each treatment in each trial/total number of cows for each treatment.

ensiled ear corn resulted in a 7.6% improvement in feed efficiency over dry ear corn. Dry shelled corn was used 2.5% more efficiently than ensiled shelled corn. Less than a 2% difference in feed efficiency was obtained between dry shelled corn and organic acid treated high-moisture corn.

The trend toward higher efficiency of nutrient utilization when high-moisture corn is compared to dry corn in some trials may be associated with the method of determining the dry matter content of the ensiled feed. Underestimation of the dry matter content of ensiled feeds would result in an overestimation of the efficiency of utilization compared to dry feeds (4, 18, 25, 50). Jones et al. (25) reported that estimation of the dry matter content of acid treated high-moisture corn using standard drying procedures can result in an underestimate of dry matter content by as much as 6%. This discrepancy results from a loss of volatile compounds from the high moisture grain during the drying process. Assuming that the dry matter content of ensiled grain was in error by 3 to 6%, this would account for the often reported improvement in feed efficiency. Thus, differences in feed efficiency must be interpreted with caution since dry matter determinations in most studies have been made using the oven drying method.

If the increased feed efficiency is a true biological response, the improvement may be due to differences in the physical or chemical properties of the grains. High-moisture corn contains more soluble nitrogen than dry corn (24, 36) and the starch may be hydrolyzed upon prolonged storage if treated with organic acids (17). These factors may influence nutrient utilization.

McKnight et al. (36) reported that the digestibility of dry matter, organic matter and energy were significantly greater when ensiled or acid treated high-moisture corn was compared to dry corn (Table 6). The high-moisture corn tended to pass through the rumen at a slower rate allowing for higher rumen digestion compared to dry corn. McCaffree and Merrill (34) using beef steers and Clark

Table 6. Digestibility of high-moisture or dry corn diets by ruminants

Type of grain in diet	Specie	No. of animals/ treatment	Moisture content of grain	Digestibility coefficients: Dry matter	Organic matter	Crude protein	Acid detergent fiber	Ether extract	Nitrogen-free extract	Total digestible nutrients	Ref. no.
			%	%							
shelled corn	Cow	20	13.4	65.4[a]	67.0[a]	64.8	47.6	66.3[a]	75.2[a]	66.5[a]	
led shelled corn	Cow	20	29.1	68.7[b]	71.2[b]	67.6	45.7	72.3[b]	80.9[b]	70.1[b]	9
shelled corn	Cow	12	11.8	64.4	65.4	67.4[a]	49.8	59.9[a]	75.1	63.7	
ionic acid shelled orn	Cow	12	19.0	59.7	61.2	62.3[b]	45.0	40.1[b]	71.8	58.7	8
shelled corn	Steer	4	11.3	79.5	81.0	69.4[a]	36.5	64.0	87.9	—	
led shelled corn	Steer	4	29.0	80.7	82.2	74.3[b]	37.3	66.0	88.7	—	
ic and propionic id shelled corn	Steer	4	26.3	79.9	81.3	70.0[a]	34.2	72.4	88.3	—	44
shelled corn	Heifer	4	11.0	74.2[a]	75.4[a]	64.1[a]	51.2	—	—	—	
led shelled corn	Heifer	4	26.2	77.0[b]	78.1[b]	67.3[a,b]	48.7	—	—	—	
ic and propionic id shelled corn	Heifer	4	22.1	77.4[b]	78.5[b]	67.3[a,b]	49.2	—	—	—	
ionic acid shelled orn	Heifer	4	22.6	77.7[b]	78.9[b]	68.5[b]	55.3	—	—	—	36

leans for a given variable within each trial not bearing a common superscript differ significantly ($P < .05$).

et al. (9) using lactating cows found that high-moisture corn contained a higher percentage of total digestible nutrients than dry corn. However, other investigators (8, 13, 30, 44, 47) have reported no difference in total digestible nutrient content of ensiled high-moisture corn and dry corn. Overall results (Table 6) indicate small differences in digestibility between ensiled or organic acid treatment of high-moisture corn and dry corn.

Rolling corn before feeding to lactating cows improved digestibility and feed efficiency. Also increased milk yields of about 2 kg per cow per day were observed in our studies (7). Wilson et al. (48) also reported an improvement in digestibility when feeding ground corn compared to feeding whole kernel corn. These data agree with the findings of Moe et al. (38) who observed that diets containing ground corn exhibited higher values for digestible, metabolizable, and net energy than did the same diet containing whole kernel corn.

A portion of the whole kernel acid treated or ensiled high-moisture barley fed to steers escaped degradation and appeared intact in the feces (1, 39). Rolling or grinding the barley improved digestibility. In our studies (7) with dairy cows when dry, ensiled or acid treated corn was fed without being rolled, a substantial amount of the corn kernels appeared in the feces. In contrast, White et al. (46) used yearling steers and found no difference in the digestibility of energy as a result of grinding the corn. The equal or improved performance observed with steers receiving whole, shelled corn compared to rolled or ground shelled corn suggests that corn need not be rolled or ground to obtain maximum performance when feeding high concentrate diets to growing finishing cattle (16, 45). The difference in response between lactating cows (7) and growing animals with respect to the feeding value of whole versus rolled corn may be due to the difference in the roughage to concentrate ratio of the diet. Embry (11) suggested that the comparative feeding value of dry versus high-moisture corn and rolled versus whole kernel corn depends upon the level of roughage in the diet, moisture content of the roughage, frequency of feeding and environmental temperature. He indicated that the greatest improvement from rolling high-moisture corn occurred when roughage made up greater than 20% of the diet. The digestibility data of Ahmed et al. (1) and the growth data of Vance et al. (45) also support the concept that the roughage to concentrate ratio of the diet affects the efficiency of utilization of whole grain.

The difference in responses from grinding or rolling corn for older animals (lactating cows (7), older steers (39)) versus young animals may be attributed to the fact that young growing animals chew their food more thoroughly than older animals. Nicholson et al. (39) indicated that 24 to 30% of the whole kernel high-moisture barley that was fed to three-year-old steers were recovered in the feces. There was no difference in nutrient content of the barley as fed and that recovered in the feces. Only 15% of the barley kernels fed to yearling heifers was recovered in the feces. Furthermore, the kernels recovered in the feces contained less digestible dry matter than the barley kernels fed to these heifers. It was concluded that the younger animals chewed the whole barley more thoroughly than the three-year-old steers and that grinding the barley resulted in a 10 to 30% improvement in dry matter, organic matter and energy digestibility. These results agree well with conclusions of Clark et al. (7) and Brundage and Allen (5) that ensiled corn and barley should be ground or rolled for older animals. Grinding or rolling grains may not be beneficial for growing animals depending on the type of diet being fed and the age of the animal.

Recommendations for Obtaining Maximum Performance from Ruminants Fed High-Moisture Grains

High-moisture grain should not be harvested until it attains physiological maturity. If the product is to be ensiled, the moisture content of shelled corn should be 25 to 30% while that for ear corn should be 30 to 35% when harvested. Conventional or oxygen limiting structures should be properly maintained and managed to ensure that the high quality grain that is harvested will be of equally high quality when removed for livestock feeding. High-moisture ear corn should be ground before ensiling. Also high-moisture shelled corn should be ground before ensiling if placed in conventional silos. Packing, so as to remove oxygen, is essential for excellent storage in conventional silos. To prevent spoilage, grain ensiled in conventional silos must be fed at a rate so as to remove at least two inches of grain per day in cool weather and three or four inches per day in warm weather. Silo diameter and feeding rate will determine the number of animals required to remove this quantity of high-moisture grain each day. Rate of removal from storage is not a factor if oxygen limiting structures or organic acid treatment is used to preserve the high-moisture grain. The manufacturers recommendations should be followed if organic acids are used to preserve the grain. Propionic acid should make up at least 25% of the acid mixture when a combination of acetic and propionic acids are used to treat the high-moisture grains (26). Extreme care must be taken in treating ground high-moisture ear corn because the cob absorbs large amounts of the acid resulting in a nonuniform treatment of the grain. Therefore, more acid may be required to preserve ground high-moisture ear corn than to preserve high-moisture shelled corn. Providing recommended practices are followed, ensiling or organic acid treatment of high-moisture grain are satisfactory ways to preserve high-moisture grain for livestock feeding.

High-moisture grains properly stored and fed to dairy cows are at least equivalent to their respective dry grains. However, to achieve equal animal performance more high-moisture grain must be fed compared to dry grain because of the greater moisture content. Since the feeding value per unit of dry matter stored as dry or high-moisture grain is about equal, the overall cost and convenience of storage and how each system of storage fits the overall operation of the farm should be the major factors in determining the method to use in feeding dairy animals.

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FEEDING MANAGEMENT SKILLS

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The chemical composition and nutrient availability of high moisture grains vary considerably. This variation is a result of the grain being processed, method of processing, moisture level of grain, and length of time ensiled grain is stored prior to feeding.

High moisture corn fed at one feedlot is usually different from high moisture corn fed at another feedlot. One feedlot's success with high moisture corn may be another's failure. The key to success or failure hinges upon management. Special efforts must be exerted to assure that quality high moisture ensiled grain reaches the cattle. Management skills of feeding pit stored, ground high moisture corn to cattle will be discussed as related to practical feedlot nutrition and feed bunk management.

Many of the adverse feelings associated with high moisture corn resulted from early bad feeding experience. Orginally it was believed that the moisture level of corn needed to be 30% to ensile and keep properly. Ensiled corn at the 30% or above moisture level is a very temperamental ingredient. It was unfortunate that such high moisture corn was initially substituted into rations which previously contained dry corn. Generally these finishing rations contained less than 10% of the dry matter as roughage and a protein supplement high in non-protein nitrogen. This combination of factors, plus high moisture corn, led to reduced feed intake, poor gain, and bad conversions. There are several practical solutions to avoid these "pit falls" in feeding high moisture corn.

High Moisture Corn Peculiarities

High moisture corn is chemically different from dry corn and must be treated as a seperate ration ingredient. Availability of energy and solubility of protein increase as the moisture content of the ensiled corn increases from 22% to 30%. As the moisture content increases, the high moisture corn tends to deteriorate more rapidly in the feed bunk. Since these factors are not all desirable, a compromise on a practical moisture level is necessary. Moisture content of corn between 25% and 27% have been ensiled and fed successfully. Bunk management is less complex with high moisture corn at 26% moisture than with corn at 30% moisture. Special care must be taken to assure that grain at the lower moisture levels is packed adequately in the pit.

High moisture corn should not be used as the only grain source in the ration. High moisture corn may be substituted for a portion of the dry grain in the ration, but this must be done on a dry matter basis. Steam flaked corn compliments high moisture corn, improves ration utilization, and extends the bunk life of the feed. Thinner flakes appear more desirable when at lower levels of addition to rations containing high moisture corn. Heat processing lowers nitrogen solubility in grains, therby reducing total nitrogen solubility of the ration. Processed dry grains have been fed successfully in combination with high moisture corn from 25% to 75% of the grain dry matter in finishing rations. Sifting of high moisture corn and rejection of fines were noted with only 10% high moisutre corn in the ration. Urea and non-protein nitrogen supplements have worked poorly with rations containing large amounts of high moisture corn. Very low levels of urea (0.05 lbs. of urea per head per day) have been fed satisfactorily with high moisture corn in finishing rations which contain at least 60% of the grain dry matter as steam flaked corn.

Roughage Level

Finishing feedlot rations containing high moisture require a minimum of 13% roughage on a dry matter basis to achieve acceptible dry matter intake. Although considerable corn silage is fed in combination with high moisture corn, good quality chopped alfalfa hay is the roughage of choice. Alfalfa hay decreases soluble nitrogen,ration moisture and hedges against trace mineral deficencies. It also tends to increase the bunk life of the feed.

New cattle, especially highly stressed light cattle, find starting rations of corn silage and high moisture corn quite unpalatable. Alfalfa in place of corn silage is valuable in starting cattle on rations with high moisture corn. Starter rations containing about 40% of the ration corn as high moisture corn appear to be less likely to produce acidosis than when all corn is steamed flaked.

Bunk Management

Bunk management is a very important part of a high moisture corn feeding program. Bunk management, over simplified, is the right amount of the right ration at the right time. Yet, one must never forget that he is feeding the cattle and not the bunk.

At most feedlots, the individual responsible for bunk management is referred to as a "feed caller", "bunk reader", or "bunk rider". He must be an intelligent, responsible individual with the authority and capability of seeing that the cattle are fed correctly. With high moisture corn in the ration, an experienced feed caller can do an acceptable job on 20,000 to 25,000 cattle. With a set of properly formulated rations, the feed caller can be the key to success or failure with high moisture corn.

The importance of observing the feed bunk and cattle several times daily cannot be over stressed. The feed bunk is the first place to notice any major change in a pen of cattle. Minor problems, such as head cables that are too low or manure buildup on bunk aprons, cause slight reduction in intake. The feed caller should see that those problems are corrected. If a pen of cattle eats abnormally less or more feed than usual, the feed caller should determine the reason. If the cattle are not sick, then feed, water, or weather is the probable cause.

Maintenance of Ration Quality

Prevention of deterioration of high moisture corn in bunks is of prime importance. Stale or moldy feed causes cattle to consume less that the normal amount of dry matter. When feed becomes stale, the extent of spoilage dictates whether cattle are given ample opportunity to consume the feed or the bunk is manually cleaned. It is necessary with high moisture corn in the ration that cattle "slick up" the bunk every two days.

When high moisture corn is in the ration, it is more important to feed at least twice a day. At each feeding empty or low bunks should be fed first and the remaining cattle be fed in an organized pattern. This will enable the majority of the cattle to be fed approximately the same time each feeding.

After each feeding, the feed caller must look at his bunks to determine if the daily call needs adjustment. The feed caller should observe the bunks and cattle a minimum of three times daily. The sooner a problem is spotted, the quicker it can be corrected.

Eating patterns of cattle vary with the season of the year and the cattle must be fed accordingly. Cattle consume the majority of the feed during the comfortable period of the day. They eat primarily during the late evening, night, and early morning in hot weather, and from mid-morning to late afternoon in cold weather. This pattern should be used in determining the amount of feed to be fed each feeding. Empty or low bunks should be fed at least one-half of the daily feed each feeding. During the hot periods of the year, to reduce bunk spoilage and match work and cattle schedules, two-thirds of the feed sould be fed at the afternoon feeding. All ration changes should be made during the afternoon feeding. This enables the feed caller to observe the cattle and eliminates the possibility of feeding hungry cattle a new ration of higher energy value. Also, it decreases digestive upset problems and prevents associated acidosis and founder from occuring.

Water

An ample supply of clean water is essential for optimum performance. Problems which limit water intake limit feed intake. It is quite simple; no water and cattle soon stop eating. It is primarily a responsibility of the pen rider to check each water trough daily. Cattle will probably have been out of water at least one feeding before the feed caller will notice an abnormal amount of feed in the bunk. Dirty water troughs are probably the most overlooked and easiest corrected problem in the feedlot.

Weather

Weather conditions and abrupt weather changes affect dry matter intake of cattle. The barometer, current weather, and anticipated weather are guides a feed caller can use in predicting intake. Generally, intake increases prior to a storm and decreases afterward.

When winter storms or bizzards occur, it is advisable to increase the roughage content of the ration. If steam flaked corn is in the ration, decrease the pressure on the rolls to decrease processing. These steps reduce the possibility of digestive upsets due to intake variation.

Rainy weather creates problems in the feedlot. Wet feed must be either eaten or cleaned from the bunk. Cattle should be given ample opportunity to eat the wet feed. Residue left in the bunk will mold rapidly if not removed. It is advisable to see the bottom of the bunk the day after a rain to insure no wet feed remains.

During stable weather conditions, daily dry matter intake does not vary more than 5% to 10%. Feed callers may cause intake to appear to vary more than this due to over or under feed predictions. If more feed than the cattle will consume is placed in the bunk today, then tomorrow less feed should be fed. The cattle may have eaten the same amount of feed each day, but the records will indicate variation.

Conclusion

High moisture corn is a seperate feed ingredient. Success is management which begins when newly harvested corn arrives at the feedlot and ends after it is consumed by cattle. One must always remember that bunk management is actually cattle management.

CHEMICAL INDICES OF QUALITY OF ENSILED HIGH MOISTURE CORN GRAIN[1]

John H. Thornton

Rather than review the literature, much of which has been written by preceding speakers, this discussion will center on data collected here in Oklahoma this past year. First let's define silage quality and examine what variables we might measure in order to estimate quality (table 1).

To quote from a speaker at the 2nd International Silage Research Conference, Asmund Ekern, "Silage quality is generally used to denote not the nutritive value -- but rather the extent to which the silage fermentation has been successful". (1) Although he was speaking about forage silage, a similar situation exists when describing quality of ensiled corn grain. Quality can refer to either ensiling success or animal performance.

The highest quality product in reference to ensiling success, as measured by nutrient preservation or stable storage, may not be the best quality product for animal performance. Just considering animal performance alone, the product indicated best by intake standards might well be more poorly digested than another silage which is less readily consumed. Likewise quality measured by weight gain or feed efficiency might select still other products. So silage quality can and does mean different things and an optimum product depends upon individual circumstances.

How can we measure quality? The list on the right (table 1) includes many of the parameters which can be quantitated although other fermentation products and nitrogen components are formed and sometimes have been measured. Not included are normal nutrient determinations applicable to all feedstuffs.

Of the parameters listed, perhaps all but the digestibility measurements would be useful in estimating ensiling success. A low pH with lactic acid the predominant organic acid would generally indicate high quality relative to ensiling success. Elevated levels of butyric acid and greater soluble N, especially NH_3-N, would indicate poorer quality.

Which of these parameters would best predict the different criteria of animal performance is less certain. Fermentation products and soluble nitrogen compounds have been implicated in reduced intake (6). Extended fermentation may improve digestibility (5). High levels of lactate have been suggested to increase efficiency (3) and feeding ensiled corn does often result in an advantage in feed efficiency compared to dry corn.

To my knowledge no one has attempted to construct a quality index for ensiled high moisture corn. Such an index could relate limits for the parameters listed on the right with a quality grade for each of the different criteria listed on the left.

The following data have been collected from corn obtained from pit silos in Western Oklahoma and Kansas. In discussing this data two main ideas will be emphasized. First, there is a great deal of variability in the ensiled

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[1]This study was supported in part by Grain Utilization Research, Box 802, Garden City, Kansas.

high moisture corn sampled. And second, there are definite relationships between some of the variables measured.

Table 2 summarizes a preliminary study (5) of ensiled corn grain samples obtained from five pit silos. Color ranged from light to quite dark. There was a large range in dry matter (DM), from 68 to 77%, and geometric mean (2) particle size varied from 1.2 to 4.1 mm. Compaction, measured with a sharp probe attached to a dial-indicator, varied somewhat between silos. Lactic acid ranged from 0.5 to 1.8% on a dry matter basis. A dramatic difference in soluble nitrogen (4) was observed from 73 down to 31%. About two-thirds of the soluble N was non-protein nitrogen (NPN). Nitrogen which was not solubilized by pepsin digestion ranged from 7 to 16% of the total nitrogen. Dry matter digestibility (DMD) estimated by an in vitro procedure suggested extremely large differences existed between silos. Some of these differences seemed to be related in that the wettest material, 68% DM, had the highest lactic acid, soluble N and DMD while the driest material, 77% DM, had the least lactic acid, soluble N and DMD. Effects of particle size and compaction were less apparent.

The large differences between silos, especially in IVDMD, suggested it should be possible to alter ensiled corn grain characteristics if enough was known about cause and effect. To confirm these observations additional samples were obtained and these and additional measurements were made. To date samples from 12 additional pit silos (table 3) have been analyzed. First note the variation found both between and within silos.

Color ranged from bright, almost like dry ground corn, through yellow to some very dark samples. Color varied within some silos with alternate grayish and yellowish layers present. Mean DM ranged from 65 to 78% with as great a range present within 2 silos as between silos. Other silos exhibited virtually no variation in DM in the samples analyzed. Mean particle size varied from 1 to over 4 mm but were generally quite uniform within a given pit. Compaction measurements were made in only 3 silos but large differences between and within these silos were found. In two silos with grayish and yellowish layers present, the grayish layers registered lower in compaction by the probe method used. Since the layers were often quite narrow and the particle size was similar there was no reason to believe these layers were packed any differently when the silo was filled. Several explanations for the within silo variation in compaction seem possible. The gray layers were about 10% units wetter and the greater moisture could allow the probe to enter the material more easily. Higher moisture material may not pack as well as drier material. Higher moisture could also result in extended fermentation resulting in some dry matter loss.

The parameters pH, lactic acid and acetic acid should indicate extent and to some degree type of fermentation. The range in mean pH from 3.7 to 4.7 is quite large. The variation within silos was relatively small, 0.3 pH units being typical. Mean lactic acid level varied from less than 0.4% to almost

2% between silos and varied almost two-fold within some silos. Mean acetic acid in the silos varied from .11 to .83% with that much variation within the silo with the highest levels.

Mean soluble N varied from 14 to 53% of total N between silos and from 11 to 60% within the first silo. Some other silos were quite uniform. A similar pattern existed for soluble NPN. Mean pepsin insoluble N values varied almost 3-fold between silos and also 3-fold within the second silo. Again, samples from some silos were quite uniform.

With these samples IVDMD was estimated in two ways. The 48 hr incubation was with wet material ground frozen through a 20 mesh screen and was an attempt to estimate maximum digestibility. The 21 hr incubations were with wet unground material and this was an attempt to estimate rate or ease of digestion. This was done with the idea that differing amounts of corn would escape rumen fermentation depending upon degree of pre-fermentation, solubilization of nutrients, particle size, etc.

As expected, a wider range in IVDMD was found between silos at 21 hr (40 to 57%) than at 48 hr (71 to 82%). At both times there was a large enough variation between silos to suggest these procedures should be verified with animal studies.

To examine the relationships between the variables measured correlation coefficients are shown in table 4. DM is significantly correlated positively with pH and negatively with lactic acid, acetic acid, soluble N and NPN and 21 hr IVDMD. The relationship with pH, lactic acid, acetic acid and soluble N are what we would expect in that higher moisture is associated with greater quantities of acid, thus reduced pH and also more extensive nitrogen solubilization.

The other parameter which can be easily altered at ensiling, particle size, is positively correlated with pH and negatively correlated with lactic acid, soluble N and NPN and IVDMD. These correlations are in the same direction as with DM, however the positive correlation between DM and particle size creates a question as to their interpretation.

Correlation coefficients among pH, lactic acid, soluble N and soluble NPN are all above .67 and highly significant. This implies that extent of fermentation was affecting these four variables quite similarly. Surprisingly none of the four were correlated significantly with acetic acid implying that acetic acid level is related to factors other than extent of fermentation. Since pepsin insoluble N was measured to estimate the amount of protein unavailable to the animal, the significant negative correlations with soluble N and soluble NPN suggest that N solubilization during silo fermentation will make more corn protein available to the animal. The 21 hr IVDMD is positively correlated with those parameters indicating more extensive silo fermentation and solubilization (lactic and acetic acid and soluble N and NPN). However, these factors seemed to have little effect on 48 hr IVDMD.

Since DM and particle size are two variables which can be altered when making ensiled corn grain and many of the other parameters are correlated to these two, their relationships were examined graphically.

The first figure shows the relationship between DM and pH. Although a definite trend is evident, apparently factors other than DM are influencing pH. A very similar relationship is found for DM and lactic acid. But to illustrate the magnitude of the change in lactic acid concentration a 10% change in corn DM, in this range, was associated with only a .76% change in lactic acid.

The DM-acetic acid relationship shows that DM should have minimal if any effect on the amount of acetic acid.

The DM-soluble N relationship shows that we could expect marked reduction in soluble N levels by going to higher DM grain. A shift of 1% unit of DM would be expected to decrease soluble N 4% units. Similar changes in soluble NPN could be expected as illustrated by the very close relationship between soluble N and soluble NPN.

The DM vs pepsin insoluble N relationship is poor as shown in the figure. Likewise not much of the variation in 48 hr IVDMD is explained by corn dry matter. On the other hand, 21 hr IVDMD was significantly correlated with DM and these data predict a 1.4% decrease in digestibility for each 1% drier material.

Particle size was also significantly correlated with many of the variables measured and this figure shows the particle size, lactic acid relationship. From **figure 9** it is evident that there isn't a normal distribution in particle size. In examining the data, we found that the 7 data points on the right represent samples from 3 silos which had an average DM content of 76.9%. The abnormal distribution in particle size together with their high DM content apparently explains the significant correlation between DM and particle size. It may be of interest to note that the grain for the three silos with larger particle size was prepared by rolling whereas tub grinding was the predominant method of preparation for the other silos.

The effects of DM and particle size were also examined by multiple linear regression using DM and particle size as the 2 dependent variables. Only in the case of 21 hr IVDMD did this appear to improve the fit over the linear regression with DM alone. The particle size - 21 hr IVDMD relationship is shown in figure 10. This does suggest that smaller particle size material might be digested faster as would be expected.

Combining N solubility and digestibility measurements enable prediction of expected changes in nutrient utilization from ensiled corn differing in DM.

Pepsin insoluble N values should indicate the amount of corn protein totally escaping digestion and soluble N values are indicative of the corn nitrogen digested in the rumen. The remainder of the nitrogen should be presented to the intestine for digestion. This fraction would represent corn protein which bypasses the rumen and is available for digestion and absorption in the lower tract. The graph (figure 11) shows this quantity could increase more than two-fold in the range we have been considering.

Similarly, the 48 hr IVDMD values represent total digestion by the animal and a shorter DMD period, 21 hr values as an example, should relate to rumen degradation. The difference represents the amount of DM which escapes rumen degradation and is available for digestion in the lower tract. This amount is depicted graphically here, with the bypass protein fraction removed on the lower edge, illustrating that starch bypass would increase as corn DM increases.

If these types of assumptions are valid they would suggest that the UFP value for ensiled corn grain would change with % dry matter. Greater corn starch bypassing the rumen would tend to decrease UFP and greater corn protein by-pass would tend to increase UFP. If an increase in corn DM affects nitrogen solubility to a greater extent than starch, the result would be increased UFP value.

In summary:

1. Ensiled high moisture corn can differ markedly in composition, even within a given silo.

2. Several characteristics of ensiled high moisture corn appear related to moisture level.

3. Ensiling drier corn should result in:

   A. Lower levels of organic acids.
   B. Reduced solubilization of nitrogen.
   C. More corn protein bypassing rumen fermentation.
   D. More starch bypassing rumen fermentation.

4. Ensiling drier corn may result in:

   A. Problems with preservation.
   B. Lower total dry matter digestibility.

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TABLE 1. CHEMICAL INDICES OF QUALITY

CRITERIA	PARAMETERS
1. ENSILING SUCCESS	PH
NUTRIENT PRESERVATION	TITRATABLE ACIDITY
STABILITY	FERMENTATION PRODUCTS
	LACTATE, ACETATE
2. ANIMAL PERFORMANCE	PROPIONATE, BUTYRATE
	ETHANOL, MANNITOL
ACCEPTABILITY-INTAKE	NITROGEN
DIGESTIBILITY	SOLUBLE N
EFFICIENCY	NH_3-N
GAIN	PEPSIN DIGESTIBILITY
	DRY MATTER
	DENSITY
	COLOR
	PARTICLE SIZE
	IVDMD
	TEMPERATURE

TABLE 2. ENSILED CORN GRAIN CHARACTERISTICS (1975)

SILO	COLOR	D.M.	PARTICLE SIZE	COMPACTION	LACTIC ACID	SOLUBLE N	SOLUBLE NPN	PEPSIN INSOLUBLE N	IN VITRO DMD
#		%	MM	UNITS	%	----%TOTAL N		--------	%
1	LIGHTEST	68	2.8	18	1.8	73	48	7	76
2	LIGHT	70	1.2	22	1.4	67	42	9	70
3	DARKEST	73	1.3	28	1.0	52	40	11	67
4	DARK	74	1.8	23	1.0	61	42	9	70
5	REDDISH	77	4.1	23	0.5	31	22	16	60

TABLE 4. CORRELATION COEFFICIENTS BETWEEN CHARACTERISTICS OF ENSILED CORN GRAIN

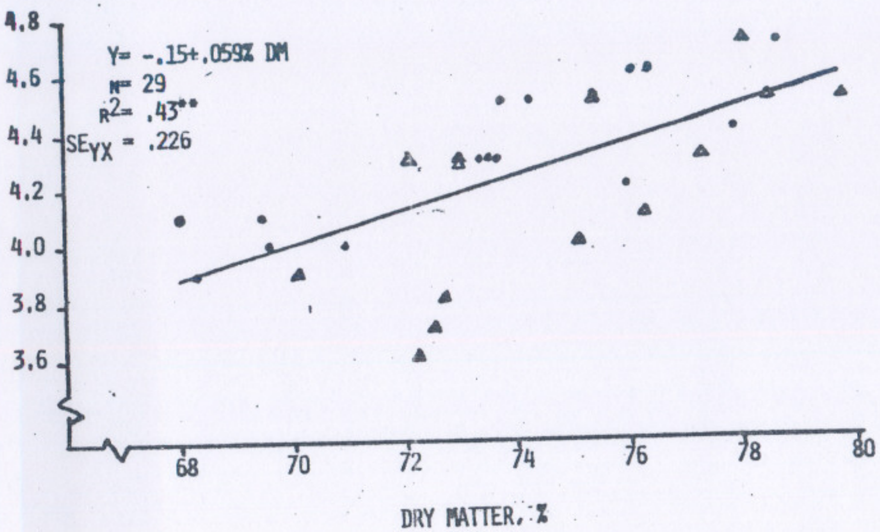
	D.M.	pH	LACTIC ACID	ACETIC ACID	SOLUBLE N	SOLUBLE NPN	PEPSIN INSOL N	IVDMD 21 HR	IVDMD 48 HR
pH	.65**	------	------	------	------	------	------	------	------
LACTIC ACID	-.69**	-.87**	------	------	------	------	------	------	------
ACETIC ACID	-.42*	-.11	.32	------	------	------	------	------	------
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 3. ENSILED CORN GRAIN CHARACTERISTICS (1976)[a]

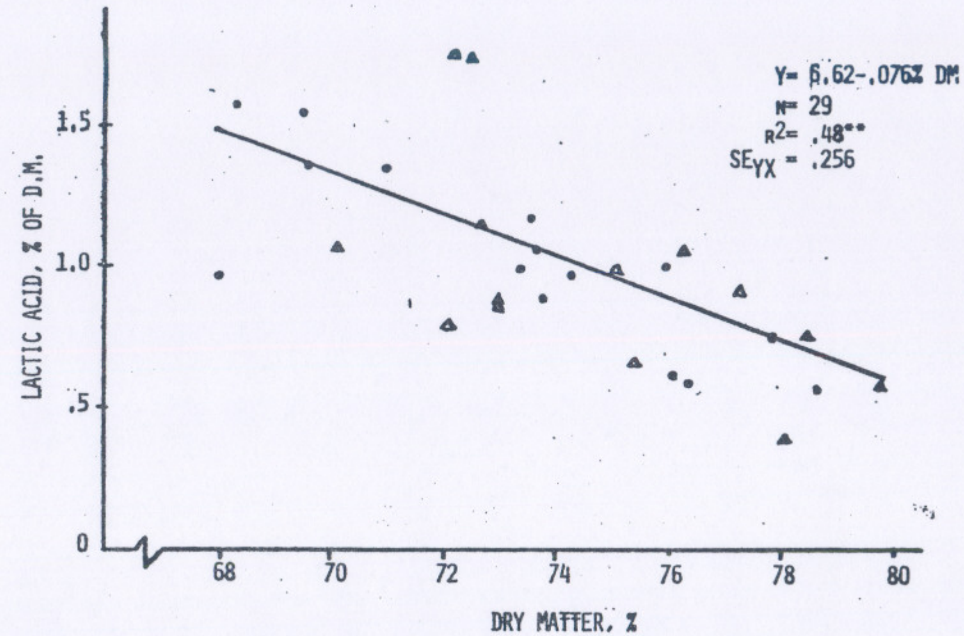
Silo	Samples	Color	D.M.	Particle Size	Compaction	pH	L.A.	A.A.	Soluble N	Soluble NPN	Pepsin Insol. N.	IVDMD 48 hr	IVDMD 21 hr
#	#		%	mm	units	units	-----%------		------% total-N--------			------%------	
1	5	varied	69.2	1.43	31.2	3.98	1.13	.83	35.8	33.2	22.3	78.2	56.3
			1.4	.04	7.9	.07	.57	.73	22.7	22.1	7.8	4.1	4.0
2	3	varied	71.8	1.37	19.6	4.03	1.31	.36	41.6	38.7	20.3	81.1	57.2
			3.9	.15	8.0	.17	.29	.04	20.6	20.9	6.0	2.9	3.9
3	1	bright	76.4	.99	50.9	4.65	.59	.12	14.0	11.6	37.7	79.4	51.3
			--	--	2.5	--	--	--	--	--	--	--	--
4	3	light	73.6	1.60	--	4.30	1.07	.44	30.0	26.9	16.6	81.5	54.4
			0.2	.22	--	.03	.09	.26	3.3	2.4	2.7	2.4	0.2
5	3	varied	74.7	3.38	--	4.52	.83	.38	23.8	22.0	28.9	77.5	43.4
			1.2	.22	--	.06	.18	.29	8.2	8.0	8.8	2.9	2.5
6	2	dark	65.2	1.93	--	3.95	1.96	.27	50.6	46.8	18.3	78.4	56.8
			6.0	.37	--	.16	.59	.10	8.6	9.6	3.7	2.0	1.2
7	3	dark	76.2	1.85	--	4.10	.99	.21	48.5	42.1	13.5	72.1	43.3
			1.1	.39	--	.20	.08	.02	7.5	2.5	1.2	0.2	7.1
8	3	yellow	72.7	1.68	--	4.30	.85	.11	45.2	38.7	13.3	76.3	48.3
			0.5	.08	--	.00	.06	.02	3.7	3.7	1.9	1.7	2.3
9	3	yellow	77.9	3.70	--	4.50	.67	.13	27.3	20.9	16.3	75.6	40.2
			2.3	.42	--	.10	.08	.01	3.1	2.3	2.7	2.7	5.7
10	3	yellow	71.6	1.63	--	3.70	1.52	.14	49.0	38.3	16.1	77.3	49.5
			1.3	.17	--	.20	.39	.03	6.4	6.7	8.9	2.9	5.8
11	1	dark	78.1	4.28	--	4.70	.38	--	17.3	16.7	13.5	70.6	54.6
			--	--	--	--	--	--	--	--	--	--	--
12	1	dark	72.7	1.69	--	3.80	1.14	.22	53.0	49.7	28.6	77.2	50.6
			--	--	--	--	--	--	--	--	--	--	--

[a]Values are means with S. D. given under each mean.

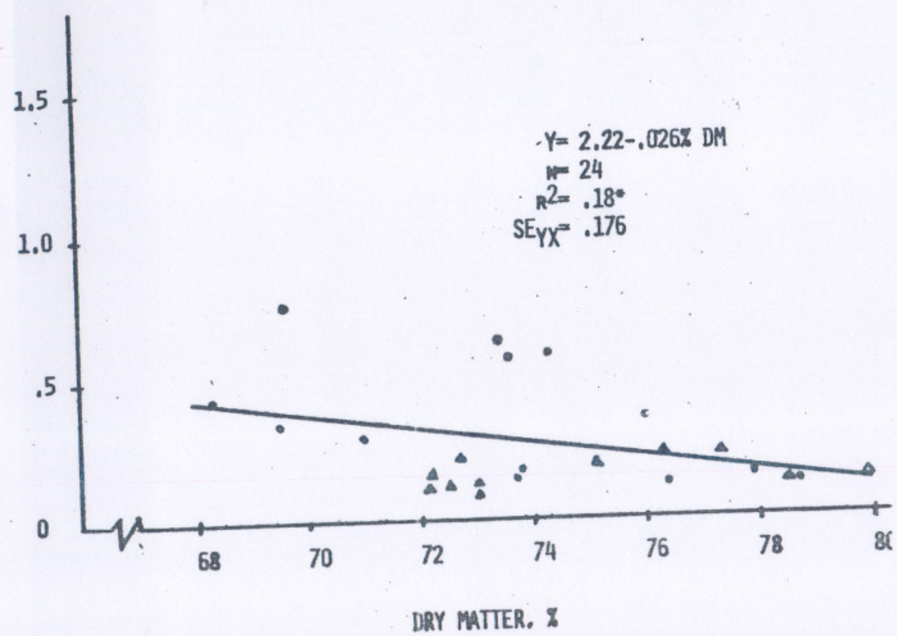
1. RELATIONSHIP BETWEEN % DRY MATTER AND pH



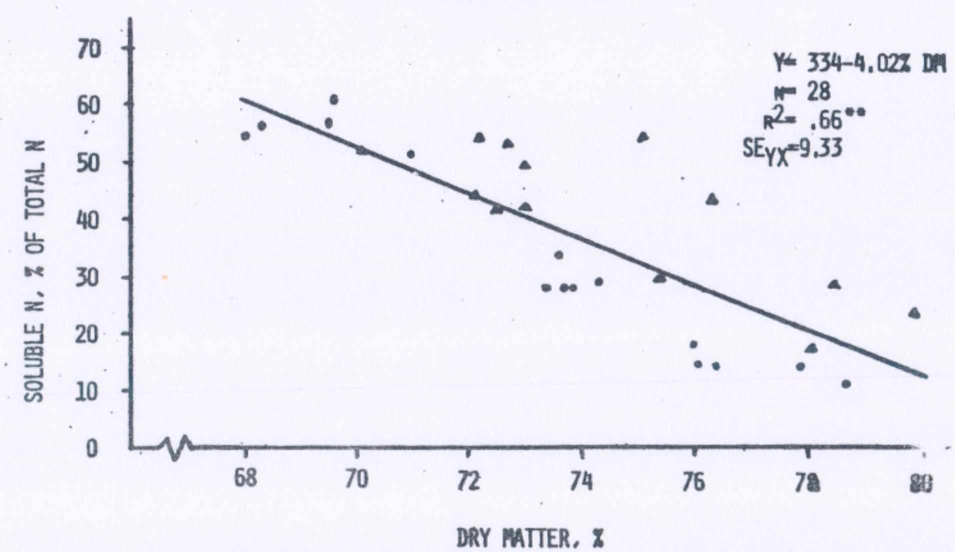
2. RELATIONSHIP BETWEEN DRY MATTER AND LACTIC ACID



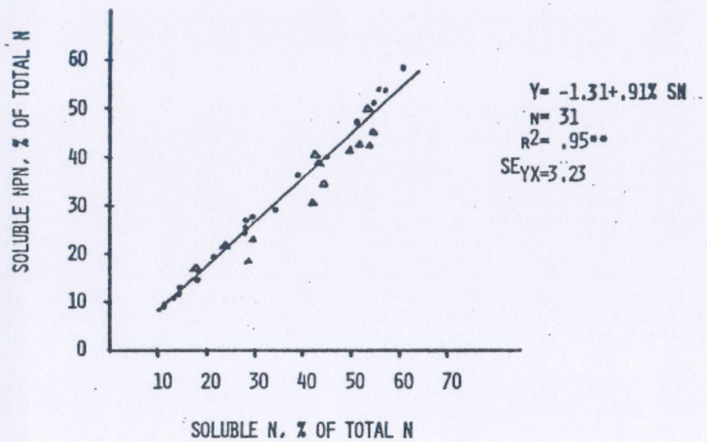
3. RELATIONSHIP BETWEEN DRY MATTER AND ACETIC ACID



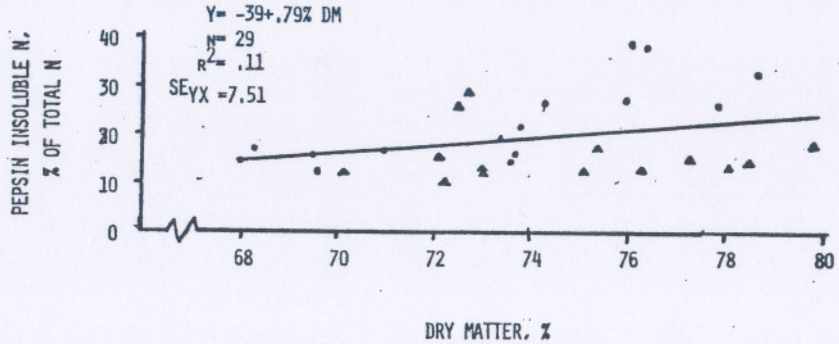
4. RELATIONSHIP BETWEEN DRY MATTER AND SOLUBLE NITROGEN



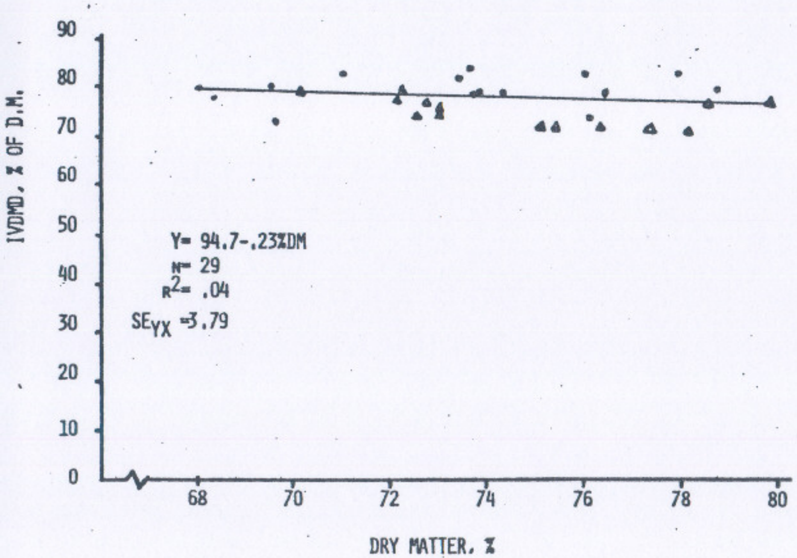
5. RELATIONSHIP BETWEEN SOLUBLE NITROGEN AND SOLUBLE NPN



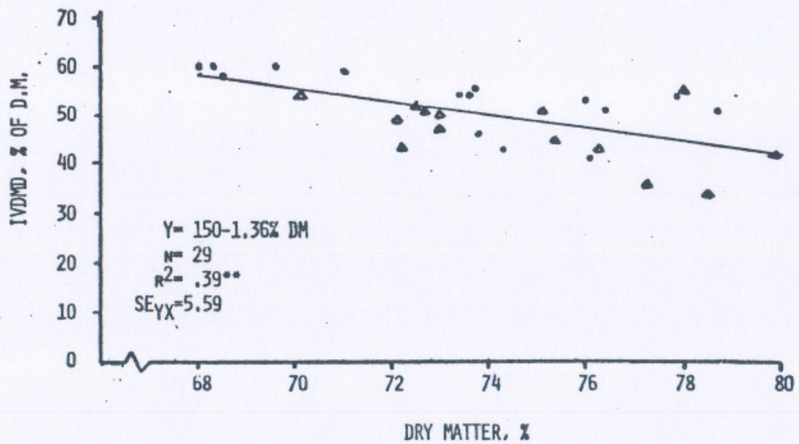
6. RELATIONSHIP BETWEEN DRY MATTER AND PEPSIN INSOLUBLE NITROGEN



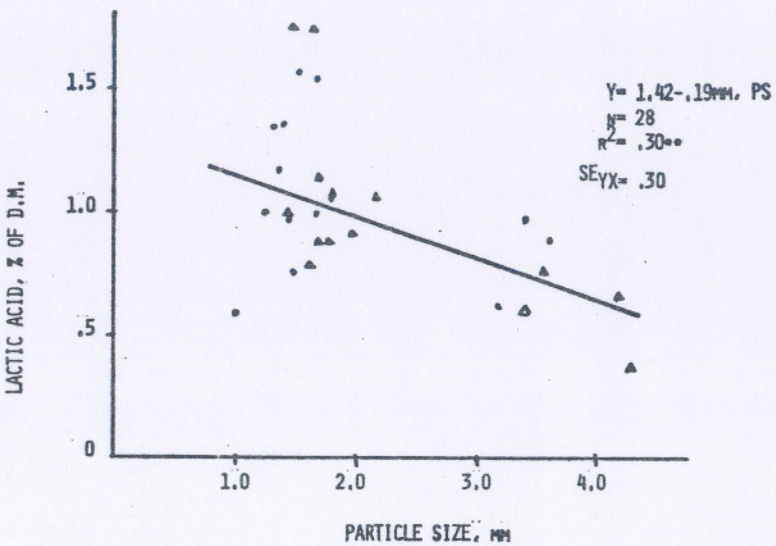
7. RELATIONSHIP BETWEEN DRY MATTER AND IN VITRO D.M. DISAPPEARANCE IN 48 HRS. (FINELY GROUND)



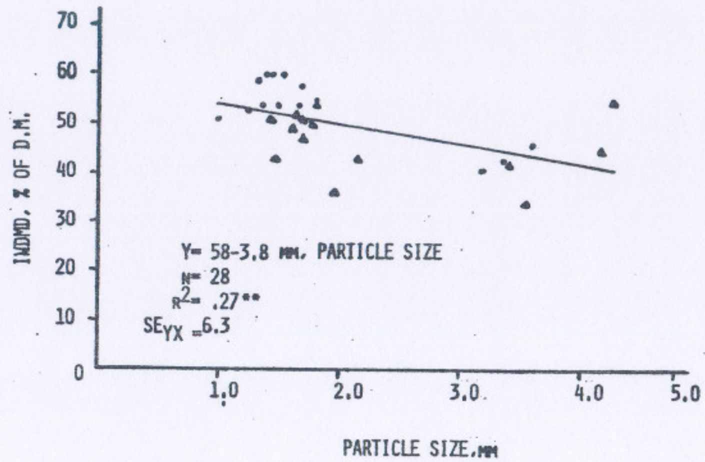
8. RELATIONSHIP BETWEEN DRY MATTER AND IN VITRO D.M. DISAPPEARANCE IN 21 HRS. (UNGROUND)



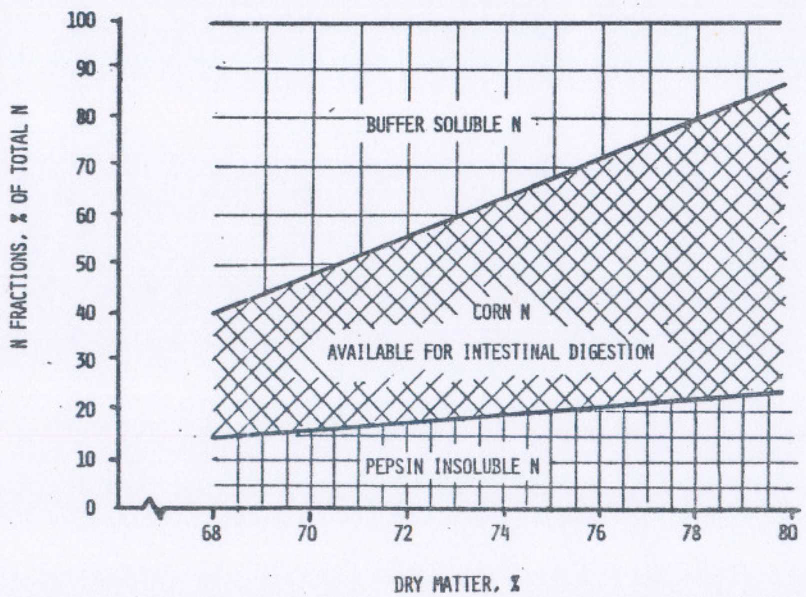
9. RELATIONSHIP BETWEEN PARTICLE SIZE AND LACTIC ACID CONCENTRATION



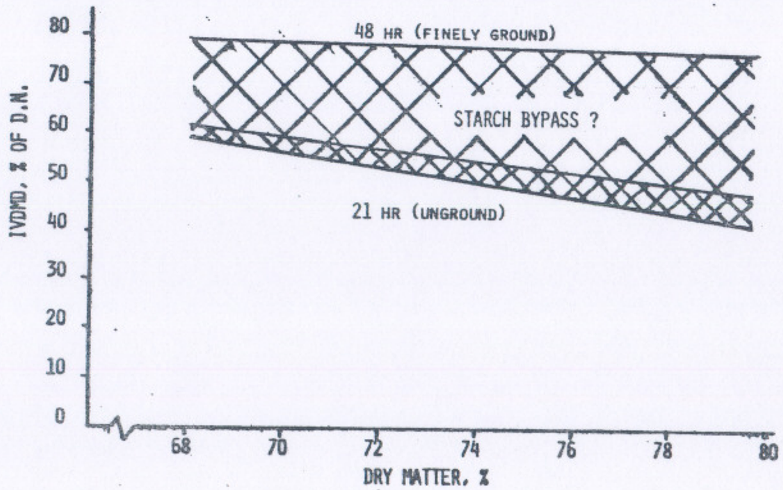
10. RELATIONSHIP BETWEEN GEOMETRIC MEAN PARTICLE SIZE AND IN VITRO D.M. DISAPPEARANCE IN 21 HRS. (UNGROUND)



11. RELATIONSHIP BETWEEN DRY MATTER AND CORN NITROGEN POTENTIALLY AVAILABLE TO THE INTESTINE



12. RELATIONSHIP BETWEEN DRY MATTER AND CORN DRY MATTER POTENTIALLY AVAILABLE TO THE INTESTINE



Symposium on Methods of Improving the

Utilization of High Moisture Grain for Cattle

Oklahoma State University
Stillwater, Oklahoma
July 22 & 23, 1976

"Digestive Disorders and Feeding Problems of High Moisture Corn and A Soluable Protein Concept for Evaluating Rations."

by

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One of the first modern observations of the problems encountered with feeding ground high moisture ensiled corn (Zea Maize) to finishing feedlot cattle was first published by this author in the November 1969 issue of "Feedstuffs Magazine" (Sprague and Breniman, 1969).

SOLUBLE CRUDE PROTEIN CONCEPT

At that time we reported problems similar to feeding high levels of non-protein-nitrogen when certain kinds of high moisture corn was fed to cattle. In one case symptoms similar to ammonia toxicity were seen -- excessive salivation, fast breathing and reduced feed intake. We suggested the soluble protein content of ground ensiled corn may be the cause of the feeding problem.

While "unraveling" the management problems of feeding high moisture corns of all kinds -- whole oxygen limited, course ground ensiled, fine ground ensiled -- we found little hard data to use. First of all the research of James Everett and Donald Hillman was recalled. Hillman now of Michigan State University, and Everett, now of Ralston-Purina, while working in the laboratory of Huffman and Emery at Michigan, harvested three systems of alfalfa-grass hay.

They harvested and fed every other wind-row of:

-- field dried alfalfa-grass hay,

-- direct cut alfalfa-grass hay silage,

-- wilted alfalfa-grass "haylage" stored oxygen limited.

In general their data indicated, one pound daily gain for the dry and wilted hay, but the direct cut hay silage limited the gain to one-third pound per day. A dry matter depression was reported for direct cut silage. Appetite was not depressed when "water soaked" hay was fed or when acid was added to "water-soaked" dry hay. Their conclusion was "not water and not acid but some other end product of fermentation of the hays."

Dr. Dale Waldo, now at the USDA Beltsville, Maryland Experiment Station, proposed that a nitrogen fraction of fermentation of hay silages would depress feed intake and milk production in dairy cows (Waldo, 1968).

Baumgardt (now at Penn. State), while working at Wisconsin Experiment Station, was one of the first modern scientists to measure and report the soluble nitrogen in fermented feeds and suggest they may contribute to feeding problems (Baumgardt, 1967). Baumgardt's review is a valuable report of the chemistry of the nitrogen fermentation of hay silages and other fermented feeds, and the effect on cattle performances.

Sprague and Breniman, 1969, suspected the nitrogen fermentation of ground ensiled high moisture corn may be the key problem associated with feeding problems of this grain storage system.

TESTING FOR SOLUBLE CRUDE PROTEIN

Breniman developed a simple procedure for testing for either ethanol or water soluble nitrogen. He used either ethanol or water in the fat extraction apparatus in his laboratory. After an overnight extraction, he analyzed the remainder on the "thimble" for N. Thereby he measured the insoluble N or insoluble crude protein. The soluble crude protein was reported by difference from the original crude protein from the sample.

It soon became possible to predict the soluble crude protein from different silos by moisture content. (See Table I) From these field observations, the moisture level was found to be related with the fermentation level and the amount of the soluble crude protein.

Data was also reported from miniature silos, where the findness of the grind and the moisture level were associated with the amount of soluble protein and other measures of fermentation such as pH and lactic acid content. (See Table II and III).

WHAT IS SOLUBLE CRUDE PROTEIN

What is soluble nitrogen or soluble crude protein? What are the predominant nitrogen compounds in fermented feeds. Please refer to this conference proceedings. Baumgardt, 1968, said these compounds are free amino acids and decarboxylated amino acids (amines). Baumgardt also reported the amines themselves have potent biological activity. High levels of ammonia have been reported from haylages. Bergen and his group at Michigan have led the way in identification of the compounds

TABLE I: High moisture corns in feedlot rations[1]

Moisture %	Soluble protein* (% of crude protein)
19.9	30.3
20.7	34.9
21.0	30.1
23.0	33.0
23.4	47.6
23.8	24.2
23.9	17.7
24.1	25.8
24.1	28.9
24.5	34.0
25.4	32.9
25.5	45.4
25.6	27.3
25.9	30.5
26.5	29.9
26.8	35.0
27.3	38.9
27.6	29.3
27.7	34.0
28.0	30.1
29.2	35.6
29.9	59.4
30.5	62.5
30.9	67.0
31.7	47.5
32.0	64.9
32.9	57.1
39.5	58.8
33.6	50.6
37.3	55.7
42.8	60.2

[1]Regression coefficient of high moisture and soluble protein = 2.0; correlation coefficient = 0.73.

* Ethanol soluble crude protein.

TABLE II: Fermentation of reconstituted dry corn (miniature silos), stored cracked vs. ground

Experiment Number	Treatment	pH	Lactic Acid % DMB	Soluble protein* (% of crude protein)
#1: Cracked Corn	Control corn (cracked)	..	0.01	21.7
	20% moisture, no preservative	6.2	0.05	22.8
	25% moisture, no preservative	5.7	0.29	27.2
	30% moisture, no preservative	4.4	0.83	41.9
	30% moisture, 0.5% sodium propionate	4.4	1.10	45.2
	30% moisture, 0.4% sodium bisulfite	5.8	0.08	54.6
	30% moisture, 0.5% sodium benzoate	4.5	0.90	50.0
	30% moisture, 10 gm. zinc bacitracin/ton	4.3	1.44	40.2
#2: Ground Corn	Control corn (ground)	..	0.007	16.1
	25% moisture, no preservative	6.0	0.83	31.2
	30% moisture, no preservative	4.5	1.35	41.4
	35% moisture, no preservative	4.2	0.98	44.1

* Ethanol soluble crude protein

TABLE III: Fermentation of field harvested high moisture corn (miniature silos), stored whole vs. cracked

Treatment	pH	Lactic acid % DMB	Soluble protein* (% of crude protein)
Low (25.0%) moisture, cracked			
Before packed in jars	..	0.071	31.0
No preservative, lid on	5.7	0.47	37.0
No preservative, lid off[1]	5.6	0.35	35.0
High (28.5%) moisture, cracked			
Before packed in jars	..	0.17	26.7
No preservative, lid on	4.6	0.96	42.6
No preservative, lid off[1]	4.6	1.08	45.1
Low (25.0%), moisture, whole			
Before packed in jars	..	0.054	29.0
No preservative, lid on	6.2	0.045	30.5
No preservative, lid off	6.2	0.049	29.0
High (28.5%) moisture, whole			
Before packed in jars	..	0.19	30.7
No preservative, lid on	6.0	0.21	34.7
No preservative, lid off	Molded in jars -- analysis not justified		

[1]All that was not molded at one month after opening was saved for analysis.

*Ethanol soluble crude protein.

in fermented feeds, particularly corn silage.

PIONEER RESEARCH

Before one gets excited about being "pioneers" regarding the chemistry or feeding of fermented feeds, let me draw your attention to the New York agriculture bulletin (Coppock and Stone, 1968). Here is a direct quote from their bulletin:

> "On analyzing green corn and silage from green corn in 1908, it was concluded that during silage fermentation; (a) very little change in fiber content, (b) most sugars had disappeared, (c) carbon dioxide was evolved and a number of acids appeared that had not been present originally, (d) protein nitrogen was reduced by one-half, and (e) non-protein nitrogen was gently increased. Annett, Harold E. and E. J. Russell, 1908. Composition of grain maize and silage produced therefrom. J. Agri. Sci. 2:382."

It seems impossible to believe that the problem of the nitrogen fermentation would not be rediscovered by Waldo, Baumgardt, and all the others until about 1968.

SOLUBLE CRUDE PROTEIN AS AN INDICATOR OF FEED INTAKE

This author proposes water soluble crude protein is an indicator of dry matter intake and cattle performance.

Bergen (1971) indicated that dry matter intake was negatively correlated with water soluble non-protein nitrogen levels and that this factor could be important in animal performance. Bergen was studying corn silage and cattle performance.

Prigge and Owens in their laboratory at Oklahoma State University (Prigge, et al. 1976) evaluated soluble crude protein (soluble nitrogen) and soluble non-protein-nitrogen. They reported an increase in the soluble NPN as a percent of the soluble N as the fermentation progressed from 0 to 56 days. (See Table IV) The soluble NPN becomes a greater percent as time of ensiling progresses.

TABLE IV: Soluble NPN as a percent of soluble N

(adapted from Prigge _et al_. 1976)

Days	Soluble NPN*	Soluble N*	Soluble NPN as a % of Soluble N **
0 days	7.3%	15.8%	46.2%
28 days	27.2%	33.1%	82.2%
56 days	32.1%	38.2%	84.0%

* Expressed as a % of the total N

** Expressed as a soluble NPN/soluble N

Sprague and Breniman (1968) also reported dry matter depressions on cattle eating high moisture corn. Many scientists, farmers, feed men, and veterinarians have made this observation regarding fermented feeds of all kinds.

A PRACTICAL SYSTEM OF EVALUATION IS NEEDED

It therefore appears to this author a simple procedure, such as soluble crude protein system, would be a reasonable and practical approach or procedure for field evaluation of fermented feeds.

It is this author's opinion, the Burroughs "urea fermentation potential" system for evaluating rations falls far short in developing a pratical system. And it does not evaluate the difference in the N solubility of dry corn as compared to the different kinds of high moisture corn.

Baldwin (1974) is well underway in developing ration evaluation using several chemical indicators to determine the protein, fiber (roughage), starch and factors involved with interactions.

This system of Baldwin has the potential of evaluating the usefullness or disuse of the N in fermented feeds.

Klopfenstein (1974) at the Nebraska Feed and Nutrition Conference has considered the protein by-pass of the rumen. Similar to other authors, he considers the importance of slowly degraded protein may be a better and less wasteful in protein utilization. This may be particularly important when feeding ground ensiled high moisture corn.

At our contract laboratory, we have found there is a great difference in the solubility of protein in natural, non-fermented feedstuffs. For example, the protein in soybeam meal is 25% to 30% soluble while the protein in brewers dried grains from the Coors Company is only 1% soluble in water after an overnight extraction in hot water. This may be important in overcoming the problems of feeding high moisture ensiled ground corn.

The nitrogen nutrition of fermented feeds has been the research area of Waldo for at least 15 years. In 1975, he reported another of his observations. The results of Waldo's work help evaluate the nitrogen nutrition of high moisture grains as well as all fermented feeds. Here is a direct quote from Waldo (1975).

> "Supplementing direct cut silages with urea produced no improvement but formaldehyde treated casein improved gain and plasma amino acids status in the previous experiment...
> Formic acid-formaldehyde treated direct-cut silage produced more gain than untreated silage. This greater gain resulted from a lower feed energy requirement per unit of gain and a greater feed intake. The improved gain occurred even with an eight percentage unit decrease in the digestion coefficient for nitrogen. Plasma valine, isoleucine, leucine, total essential amino acids, and essential:non-essential ratio were increased by the silage treatment. The feeding of formaldehyde treated soybean meal improved the production responses and amino acid status but urea feeding did not. These data and those obtained with casein supplementation in the previous experiment suggest that the poor performance of many hay-crop silages is due to a shortage of absorbed essential amino acids."

This may hold true for all fermented feeds.

Is the problem of reduced performance associated with the haylages, corn silages, and high moisture corn related, and is the problem particularly related to the fermentation of the nitrogen fraction? This author believes it is. Waldo is up to something!

-- How to reduce fermentation and improve the quality of fermented feeds,

-- Can the increase in solubility be valuable, or is it detrimental,

-- Does preformed (natural) protein help improve rations with excessive soluble protein,

-- Is some non-fermented feed needed or essential for maximum dry matter intake and livestock performance?

Yet Waldo, Bergen, Klopfenstein, Vetter, Clark and Hattfield, and all the others have not unlocked the one key factor or missing link.

<u>DIGESTIVE PROBLEMS AND FEEDING PROBLEMS</u> (of feeding ground ensiled high moisture corn).

Here are observations made by our staff at Wilgro Feeds as confirmed by this author. We have observed the following problems:

-- Lowered feed intake and daily gain with wet high moisture corn. This can be corrected by a coarser grind, storing the grain at a lower moisture, adding more roughage, diluting the high moisture grain with dry grain, lowering the NPN or removing the NPN, keeping the protein at an adequate level but not excessive for the productive needs of the animals. All these are "artistic" rather than "scientific" adjustments.

-- More founders-- We have observed more foundered cattle with ground ensiled high moisture corn. This is thought to be caused by either the <u>predigested availability of the grain or the acid load</u> that is eaten by the animals.

-- More enlarged legs, which we call "stock-legged condition", which leads to foot problems. This may be caused by the acid load or the fermentation rate or certain amines (histamine and others) which are present in the fermented corn.

-- More digestive upsets if an adequate roughage level is not used. It is proposed that an adequate roughage level is needed with finely ground high moisture corn just as is needed with finely ground dry corn.

-- More water bellies (phosphatic kidney stones). We have found the soluble phosphorus in ground high moisture ensiled corn to be 100% soluble after a 12 hour extraction and only 75% with dry corn. This may be the reason for more water belly problems with the high moisture grain than dry grain.

-- More thrombo-embolic meningeo-encephalitis hemophylis caused, ration involved.

T.E.M. (THROMBO-EMBOLIC-MENINGEO-ENCEPHALITIS)

It is the opinion of the author regarding relatively new cattle (first 60 days) fed fermented feeds including corn silage, high moisture grains and haylages, that a high incidence of TEM is encountered. We have not seen an outbreak with dry feeds. It is proposed the brain is either sensitive to the increased levels of blood ammonia (Baumgardt, 1967), or toxic amines from the fermented feeds is a cause in itself. When the TEM is seen the rations will analyze high in soluble protein and often the ration contains some urea.

CORRECTING A TEM OUTBREAK

The TEM can be eliminated in two to three days by changing the ration to less fermented feeds, reducing the protein in the ration, reducing the NPN level, or eliminating the NPN of the ration.

The usual procedure on calves is to increase dry roughage such as alfalfa hay 2 lb. per day, increasing the dry corn 2 lb. per day, and reducing the supplement particularly a urea supplement. High levels of tetracyclines are often used with the program, but a ration change is the most successful method of stopping the outbreak.

DESIGNING RATIONS WITH HIGH MOISTURE CORN

When evaluating rations with high moisture corn, several factors must be considered:

1. The grain itself.

    -- If stored whole (oxygen limited), little roughage is needed and a medium level of NPN can be used.

    -- If finely ground and ensiled, in either tower or "pit" or "bunker" silos, then more roughage is needed and less NPN can be used. (This is a practical rather than scientific observation.)

    -- If ground coarse or rolled coarse, an intermediate level of roughage and NPN will work.

2. The roughage in the ration.

    -- Is the roughage fermented or not fermented?

3. The protein in the ration.

    -- Are there other NPN sources in the ration such as ammoniated feeds or feeds which have a high soluble N level?

    -- Other soluble sources in the program. (Example: soybean protein is more soluble than the protein in cotton seed meal.)

    -- The total protein in the ration should not be excessive from a practical point of view. Too high a level may complicate the nitrogen (protein) status of the animal. This is justified until more research is done.

4. The buffer level of the ration.

    -- Research needs to be done in this area. Practical rations with ground ensiled high moisture corn contain limestone, either ground calcite (calcium carbonate) or dolomite (magnesium calcium carbonate). Sodium bicarbonate is used by some successful high moisture grain feeding programs.

SOLUBLE CRUDE PROTEIN SYSTEM FOR RATION FORMULATION

The next observation is a natural "spin-off" of some of the above observations. Until further work has been done, the author proposes a system for evaluating the NPN in all rations, but particularly rations with fermented feeds, such as corn silage, haylages, and high moisture grains.

Here are two ration examples. The first example (Ration 1) is with all high moisture ensiled corn, and the second example (Ration 2) uses only dry corn. Note the supplement proposed for the ground ensiled corn is a 40% supplement and a 10% crude protein from NPN. This allows 35% of the crude protein from all soluble forms including the NPN in the supplement and the soluble crude protein in the high moisture corn. This system must be followed up with subsequent laboratory analysis. In this example, the corn contained 30% moisture and 40% of the protein was estimated to be in a soluble form.

The supplement proposed for the dry corn, using this system, is a 40% crude protein and 28% crude protein from non-protein-nitrogen. The dry ration calculates 27% crude protein from all soluble sources.

SUMMARY

1. It is proposed that the water soluble crude protein level in fermented feeds is an indication of the feeding value of ground ensiled high moisture corn.

RATION 1: Ration formulation using soluble protein system (ground ensiled high moisture corn)

Ing.	DM lb. per day	Wet lb. per day	% Wet	% DM	% Cr. Pro.	Est. %[2] Sol. Pro.	% Sol. Pro.
H. M. Corn [1]	14.0	20	61	42.7	4.31	(40)	1.72
Alf. Hay	1.8	2	6	5.4	.90	(10)	.09
C. Silage	3.0	10	30	9.0	.68	(50)	.34
40 Suppl. (10 NPN)[3]	.9	1	3	2.7	1.20	(10 NPN)	.30
	19.7	33	100	59.8	7.09		2.45
					11.9 %		3.5% [4]

[1]Ground ensiled high moisture corn at 30% moisture and 40% water soluble protein was used for the example.

[2]As a percent of the total crude protein.

[3] and [4] A supplement containing 40% cr. pro. and not more than 10% cr. pr. from NPN is needed to keep the % sol. cr. protein under 35% of the crude protein.

RATION 2: Ration formulation using a soluble protein system (ground dry corn)

Ing.	DM lb. per day	Wet lb. per day	% Wet	% DM	% Cr. Pro.	Est. %[2] Sol. Pro.	% Sol. Pro.
Dry Corn [1]	14.0	16.5	55.9	47.5	4.80	(15)	.72
Alf. Hay	1.8	2.0	6.8	6.1	1.02	(10)	.10
C. Silage	3.0	10.0	33.9	10.2	.77	(50)	.38
40 Suppl. (28 NPN) [3]	.9	1.0	3.4	3.1	1.37	(28 NPN)	.95
	19.7	29.5	100	69.9	7.96		2.15
					11.9%		27% [4]

[1] Dry corn at 15% moisture

[2] As a percent of the total crude protein.

[3] and [4] A supplement containing 40% cr. pro. and 28% cr. pro. from NPN was used in the example. This level of NPN in day rations was considered "near the top range of use" for management reasons and maximum performance. Note the soluble crude protein as a % of the crude protein in this case is below the 25% level used in Ration 1.

2. Feeding problems and disturbances were discussed. Interactions with roughage, protein, NPN, buffers, and dilution with dry grain were discussed.

3. A system for evaluating rations on a soluble protein basis was proposed.

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NUTRITIONAL VALUE OF HIGH MOISTURE CORN AND MILO

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The concept of using high moisture grain in cattle feeding is certainly not completely new. In 1904 an Iowa research report showed that corn with a moisture content of 35% was equal to mature dry corn for finishing steers. Over the last 75 years cattle feeders have on occasion used either high moisture corn or high moisture milo in cattle finishing rations.

However, today we are seeing an even greater resurgence of interest in the utilization of high moisture grain. This has been compounded by the interest of grain producers in harvesting high moisture grain as a means of reducing field losses and getting the crop harvested earlier. In addition to this, new developments in the last five to ten years in storage procedures have enabled cattle feeders to store successfully high moisture grain without adverse losses due to spoilage. In particular storage systems such as the airtight silos and the use of organic acids as preservatives have kindled further interest in high moisture grains. Grinding high moisture corn and milo and ensiling in concrete trench or stave silos has become a popular practice in many areas.

The following report will pertain mainly to high moisture corn and milo since these are the most commonly used cattle feeds in Kansas and Oklahoma. However, it certainly should be noted that recent research has shown that high moisture wheat and barley can successfully be fed to cattle as well.

UTILIZATION OF HIGH MOISTURE CORN BY BEEF CATTLE

In reviewing the research available on feeding high moisture corn, it soon becomes clear that the method of storage has an influence on the nutritional value although certainly not as significant as is noted with storage systems for high moisture milo. As such the following report has been broken up into sections in which the nutritional value of high moisture corn is compared to dry rolled corn based on various methods of storage. The following four methods of storage will be considered:

1. Storage in oxygen-free or airtight silos.

2. The use of organic acid preservatives.

3. Grinding and ensiling either in a trench or concrete stave silo.

4. Reconstitution of dry grain to high moisture grain.

1. <u>The nutritional value of corn stored in oxygen-free structures</u>. In the last 10 years a considerable amount of research has been conducted at various universities comparing high moisture corn stored in an air tight or oxygen-limiting structure to corn fed in the conventional dry rolled manner. In Table 1, ten trials conducted at various locations in the United States shows that feeding high moisture corn stored in an air tight structure showed only a slight effect on the average daily gains of the cattle with there being about 1.9% improvement in average daily gains as compared to cattle fed dry corn. In contrast, feeding high moisture corn, from the air tight structures, has fairly consistently in the 10 trials improved efficiency, the average improvement being 5.6%.

2. <u>The nutritional value of high moisture corn stored utilizing organic acid preservatives</u>. In the last five years a considerable amount of research has been done of the use of organic acids (propionic, acetic, formic acids, etc.) as a method of preserving and storing high moisture grain. These preservatives have been shown to prevent mold growth, temperature increases and weight loss with high moisture grain if used properly during the storing process. It should be emphasized that proper application of the preservative during storing is very important to successful results.

From a nutritional standpoint corn stored using organic acids as preservatives has shown to be at least equal to dry rolled corn when fed in either growing or finishing rations. In fact as noted in the summary of the 19 trials in Table 2, there was actually a very slight increase in gain of 1.1% and a 2.4% improvement in feed efficiency. In particular research done in the last two years has fairly consistently shown an improvement in feed efficiency for high moisture corn, stored using an acid preservative, as compared to dry rolled corn.

3. <u>The nutritional value of ground ensiled high moisture corn as compared to dry rolled corn</u>. The system of storing high moisture grain most commonly currently being used by cattle feeders in Kansas and Oklahoma is to grind the corn at harvest time and ensile in a trench or bunker silo. This type of storage system offers the obvious advantage of not having the investment in facilities or preservatives as involved in the previously described methods of storing.

Research has also been conducted comparing the nutritional value of this ground and ensiled corn stored either in a concrete stave or trench type of silo utilizing dry rolled corn as the comparison. Unfortunately, as shown in Table 3 based on fifteen trials, high moisture corn stored in the ground and ensiling method has been slightly lower than dry rolled corn from a nutritional standpoint. Based on the average of the fifteen trials there was a 5.6% reduction in average daily gain which was coupled with about a .7% decrease in feed efficiency. As will be noted in the table, considerable variation has occurred from research trial to research trial indicating that there certainly is a need for further research in this area to understand why in some cases there has been an actual improvement in feed efficiency. One of the keys appears to be that when the entire concentrate portion of the ration consists of ground, ensiled high moisture corn along with a roughage, the feed intake is slightly reduced which accounts for most of the reduction of average daily gain. Most nutritionists and feedlot operators attempt to compensate for this by using ground, ensiled high moisture corn in combination with dry rolled or steam flaked corn and likewise they attempt to use a dry roughage to reduce the overall moisture content of the ration and improve intake. This will be discussed in detail later in the report.

4. The nutritional value of reconstituted corn. Another method of getting a high moisture corn product is to take dry corn and reconstitute with water. The reconstitution of corn has been compared to dry corn at a number of locations. The results to date by the universities have been extremely variable with some of the research results showing a positive improvement in the nutritional value of reconstituted corn and other stations reporting dramatic reductions in the nutritional value of reconstituted corn. The results tend to suggest that further research is needed in the technique of reconstitution in order to further understand when the addition of water to dry corn will improve nutritional value in contrast to why some of the results have been consistent in showing poor results.

FACTORS TO CONSIDER TO IMPROVE THE UTILIZATION OF HIGH MOISTURE CORN

1. One of the arguments against the use of corn stored in a whole high moisture form in either an air tight silo or after the use of a preservative is that it requires processing prior to feeding. In contrast those feedlots using the ground, ensiled method can feed directly from the bunker without additional processing.

A review of the research data in comparing rolled high moisture grain versus high moisture grain fed in the whole form may provide some helpful information for cattle feeders. When the high moisture grain is fed with a low level of roughage such as a ration with 10-20% roughage it appears that the grain can be fed successfully whole without any additional benefit derived from rolling prior to feeding. This is supported by the data as shown in Table 4. In contrast when high moisture grain is fed with a moderate level of roughage, there actually is a slight improvement to be derived by rolling the high moisture corn prior to feeding. This is also shown in Table 4.

2. Another management practice that cattle feeders use while feeding high moisture corn is to feed high moisture corn in combination with either dry rolled corn or in some cases even steam flaked corn. The intent is to use this as a means of achieving a more uniform intake pattern. There is a very limited amount of research available in which high moisture grains have been fed in combination with dry grain. However, an experiment was conducted in Colorado in which steam flaked corn was fed at approximately 30% of the corn portion along with about 80% high moisture corn, with the remainder of the ration being mill mix and corn silage. They were actually able to achieve slightly superior advantage in feed efficiency with this high moisture and steam flaked corn in combination as compared to steers fed predominately steam flaked corn.

3. Another management practice which some feedlots have followed is the feeding of a dry roughage such as corn stover or alfalfa hay with the high moisture grain. Again there is limited research to support this use of a dry roughage. However, in a study done at Garden City in which high moisture corn was fed with either alfalfa hay or corn silage, the steers on the alfalfa hay ration were $7\frac{1}{2}$% more efficient in converting feed lending support to the idea that the use of dry roughages may help keep cattle on feed more uniformly and stimulate more efficient utilization of the high moisture grain. It is conceivable that even some of the residue material such as wheat straw and corn stalk residue might be useful along with the high moisture ration as a means of reducing moisture in the ration. Table 6 shows those research results from the Garden City Experiment Station.

4. Other management practices associated with high moisture grain feeding include using a coarser grind on the corn as is currently being practiced by some of the feedlots utilizing a fairly newly developed roller mill. Again there are no research results to support this type of practice. In a research trial just completed at Nebraska they did mix high moisture whole corn with about 1/3 ground high moisture corn and were able to achieve comparable gains as compared to cattle that were on dry rolled corn.

5. Another practice that some of the cattle feeders are interested in is to make a high moisture ear chop in which equipment is used that will pick the cob plus the husk, chop it up and make a high moisture ear chop with approximately 32 to 35% moisture. This procedure certainly has some merit because it offers a feed which has about 20% roughage in it and may fit in well with the concept of feeding a higher roughage level in the ration. Research results with the high moisture ear chop have shown that the cattle stay on feed very successfully. This would appear to be a management and feeding practice that we may see more widely adopted in Kansas and Oklahoma. Table 7 shows 14 trials in which high moisture ear chop was compared to dry ground ear corn with the cattle having 3% better average daily gains on the high moisture ear chop which was coupled with an improvement in feed efficiency of 10%.

6. Successful use of high moisture shelled corn or ear corn may hinge on harvesting at the proper moisture level which is no easy task when grain is supplied by many growers and thousands of bushels are being stored. In Iowa research, high moisture ear corn stored at 33-38% had superior feeding value by 6% over high moisture ear corn stored at 22-32% moisture. Somewhat similar trends are noted for high moisture shelled corn with the desired storage moisture being 25-30%.

UTILIZATION OF HIGH MOISTURE MILO WITH BEEF CATTLE

Research results with high moisture milo are more limited than with corn. However, the research that has been summarized was usually conducted at either Texas, Oklahoma or Kansas and has consistently shown that cattle utilize high moisture milo considerably better than dry rolled milo. In some experiments, performance of high moisture milo stored either in an air tight structure or with an acid preservative has been nearly comparable to steam flaked milo. Table 9 shows details of fifteen research trials in which high moisture milo was fed and compared to either dry rolled milo or steam flaked milo.

Summarizing the results of method of storage in six trials in which high moisture milo was stored with an acid preservative there was an 8.8% improvement in average daily gains coupled with a 10.2% improvement in feed efficiency as compared to steers on dry rolled milo. High moisture milo stored in an air tight structure likewise has shown superior results to dry rolled milo with there being a 3.7% improvement in average daily gain and 11.1% improvement in feed efficiency. As was noted with corn, high moisture milo which was ground and ensiled in either a trench or concrete stave silo was found to be very slightly inferior to dry rolled milo with there being a 1% poorer gain coupled with 1.6% poorer feed efficiency. The reconstitution of milo has also been more successful than the reconstitution of corn especially if the milo has been reconstituted in the whole kernel form. As noted in Table 9 reconstituted milo in the whole kernel form has usually been superior to dry rolled milo. However, when the milo was ground and reconstituted performance has been about comparable to dry rolled milo.

It would be expected that management practices, which were previously discussed for high moisture corn, such as mixing high moisture milo with steam flaked or dry rolled milo and feeding dry roughages with high moisture milo, would also be beneficial with high moisture milo as they are with high moisture corn.

SUMMARY

The feeding of high moisture corn and milo is a rapidly developing management practice which should continue to grow in future years. The feeding of high moisture corn as compared to dry rolled corn showed a slight advantage, with the high moisture corn stored either in an air tight structure or acid treated being somewhat superior to ground, ensiled high moisture corn. High moisture milo, if stored in an air tight structure or acid treated, had considerably greater feed value than dry rolled milo. High moisture milo ground and ensiled was only about equal to dry rolled milo.

TABLE 1. THE NUTRITIONAL VALUE OF HIGH MOISTURE CORN (HMC) STORED IN OXYGEN FREE STRUCTURES AS COMPARED TO DRY ROLLED CORN (DC)

Reference	Days Fed	No. Cattle/ Treatment	Moisture*		Daily Gain*		Feed/Gain*		HMC as % of DC*	
			HMC	DC	HMC	DC	HMC	DC	Gain	Feed/ Gain
Nebraska	90	22	25	14	2.10	1.87	9.0	9.9	+12.3	+9.0
Nebraska	105	44	25	14	3.15	3.14	6.5	6.3	+.3	-3.2
Nebraska	161	20	23	15	2.31	2.45	7.69	7.35	-5.7	-4.6
Nebraska	105	39	24	12.5	3.01	2.89	6.51	6.89	+4.2	+5.5
Michigan	104	32	32	--	3.33	3.54	7.19	7.97	-5.9	+9.7
Iowa	165	46	27.2	10.7	2.33	2.35	7.64	7.95	-.8	+3.9
Iowa	140	34	26.6	13.8	2.38	2.20	5.82	6.62	+8.2	+12.1
Iowa	--	--	27.8	13.9	2.25	2.24	7.62	8.07	+.4	+5.6
Colorado	--	--	--	--	2.34	2.50	8.49	8.84	-6.4	+4.0
Florida	--	--	--	--	2.92	2.60	9.47	10.97	+12.3	+13.7
SUMMARY OF TEN TRIALS									+1.9	+5.6

*HMC = high moisture corn from air tight silo while DC = dry rolled corn

TABLE 2. THE NUTRITIONAL VALUE OF HIGH MOISTURE CORN STORED THROUGH THE USE OF ORGANIC ACIDS AS COMPARED TO DRY ROLLED CORN

Reference	Days Fed	No. cattle/ Treatment	Moisture*		Daily Gain*		Feed/Gain*		HMC as % of DC*	
			HMC	DC	HMC	DC	HMC	DC	Gain	Feed/ Gain
Guelph, Ont	87	18	26	13	3.08	3.19	5.6	5.65	-3.4	+.9
Guelph, Ont.	120	24	24	13	3.34	3.34	5.30	5.30	0	0
Cornell	110	10	--	--	2.27	2.24	7.54	7.79	+1.3	+3.2
Cornell	118	10	--	--	1.87	1.78	9.84	10.32	+5.1	+4.7
Nebraska	90	22	26	14	1.90	1.87	10.1	9.9	+1.6	-2.0
Nebraska	105	44	26	14	3.05	3.14	6.3	6.3	-2.8	0
Purdue	83	50	--	--	2.66	2.53	5.97	6.20	+5.1	+3.9
Purdue	126	18	--	--	2.51	2.44	6.07	6.38	+2.9	+4.9
Purdue	111	18	--	--	2.11	2.24	6.53	6.44	-5.8	-1.4
Iowa	140	17	26	14	2.02	2.00	6.90	7.13	+1.0	+3.2
Iowa	103	6	26	14	2.60	2.42	N.A.	N.A.	+7.4	+4.6
Iowa	--	--	25	14	2.60	2.58	5.46	5.66	+.8	+3.5
South Dakota	158	29	22	14	2.60	2.54	8.06	7.57	+2.3	-6.5
Iowa	151	147	25	14	2.56	2.54	5.77	5.83	-.8	+1.0
Iowa	150	156	25	14	2.58	2.54	5.33	5.70	+1.6	+6.5
Purdue	181	50	30	14	2.55	2.51	5.83	6.14	+1.6	+5.0
Purdue	181	18	27	11.6	2.42	2.38	6.55	6.87	+1.8	+4.7
Guelph, Ont.	140	12	30	13.0	3.08	2.86	5.00	5.50	+7.7	+9.1
Nebraska	93	22	25	--	1.89	1.89	10.1	10.1	0	0
SUMMARY OF 19 TRIALS									+1.1	+2.4

*HMC = high moisture acid treated corn while DC = dry rolled corn

TABLE 3. THE NUTRITIONAL VALUE OF HIGH MOISTURE CORN THAT IS GROUND AND ENSILED EITHER IN A CONCRETE STAVE OR BUNKER SILO AS COMPARED TO DRY ROLLED CORN

Reference	Days Fed	No. Cattle/ Treatment	Moisture*		Daily Gain*		Feed/Gain*		HMC as % of DC*	
			HMC	DC	HMC	DC	HMC	DC	Gain	Feed/ Gain
Guelph, Ont.	140	12	30	13	3.19	2.86	5.4	5.5	+11.5	+1.8
Nebraska	161	20	25	15	2.2	2.4	8.2	7.4	-.8	-10.8
Nebraska	90	22	25	14	1.68	1.87	10.7	9.9	-10.2	-8.0
Nebraska	105	44	25	14	2.89	3.14	6.7	6.3	-8.0	-6.3
Purdue	--	--	26.4	--	2.52	2.47	6.8	7.4	+2.0	+8.1
Purdue	--	--	34.0	--	2.27	2.45	6.81	7.03	-7.3	+3.1
Purdue	--	--	26.0	--	2.20	2.37	6.27	6.57	-7.1	+4.6
Purdue	--	--	29.0	--	2.47	2.70	6.24	6.39	-8.5	+2.3
Purdue	--	--	28.0	--	1.93	2.24	7.02	6.44	-13.8	-9.0
Purdue	170	24	29.2	11.6	2.40	2.60	6.53	6.76	-7.7	+3.4
Oklahoma	117	14	30	15	3.02	3.09	6.71	7.54	-2.2	+11.0
Illinois	120	20	24	14.5	1.90	1.89	10.43	10.48	+.5	+.5
Illinois	120	20	29	14.5	1.91	1.89	10.40	10.48	+1.0	+.8
Illinois	120	20	36	14.5	1.51	1.89	11.94	10.48	-25.4	-13.9
Colorado	134	20	Ap. 30	--	2.59	2.75	7.89	8.04	-5.8	+1.9
SUMMARY OF 15 TRIALS									-5.6	-.7

* HMC = high moisture corn; DC - dry rolled corn

TABLE 4. WHOLE VERSUS ROLLED HIGH-MOISTURE CORN WITH LOW LEVELS OF ROUGHAGE*

Station and year reported	Whole high-moisture corn Daily Gain	Whole high-moisture corn Feed per cwt. gain	Moisture content	Rolled high moisture corn Daily Gain	Rolled high moisture corn Feed per cwt. gain
	lb.	lb.	pct.	lb.	lb.
Minnesota, 1967	2.34	755	35.0	2.39	686
Minnesota, 1968	2.58	704	34.4	2.57	656
Illinois, 1970	2.84	603	26.0	2.90	568
South Dakota, 1969	2.44	890	27.4	2.27	929
South Dakota, 1970	3.30	638	29.7	3.10	646
South Dakota, 1971	2.68	872	21.9	2.75	841
South Dakota, 1971	2.62	898	21.9	2.65	876
Nebraska, 1973	3.26	620	25.0	3.05	640
Nebraska, 1973	2.15	870	25.0	2.04	920
Average	2.69	761		2.64	751
Percent change				-1.9%	+1.3%
Minnesota, 1967	1.32	378	35.0	1.36	367
Minnesota, 1968	1.39	358	34.4	1.55	324
Michigan, 1967	2.73	663	26.0	2.62	708
Ohio, 1970	2.39	825	27.0	2.32	808
South Dakota, 1970	3.16	739	29.7	3.33	696
South Dakota, 1970	2.01	929	28.0	2.06	920
South Dakota, 1970	2.08	979	28.0	2.28	922
South Dakota, 1971	2.70	819	25.7	2.70	796
Average	2.22	711		2.28	693
Percent change				+2.7%	+2.5%

*Table previously reported in 1973 U. of Illinois Beef Cattle Day Report

TABLE 5. PERFORMANCE OF CATTLE FED COMBINATIONS OF PROCESSED CORN

Treatment description	Steam Flaked Corn Plus Dry Corn	High Moisture Corn Plus Steam Flaked Corn
No. steers	60	60
Initial weight, lbs.	716	716
Final weight, lbs.	1052	1067
Average daily gain, lbs.	2.63	2.74
Average daily ration, lbs.:		
high moisture corn	--	8.13
flaked corn	9.16	2.62
ground corn	2.50	--
mill mix	6.08	6.40
corn silage	4.23	4.40
Total daily ration	21.96	21.54
Feed efficiency	8.37	7.84

TABLE 6. UTILIZED ALFALFA HAY VERSUS CORN SILAGE AS THE ROUGHAGE WITH HIGH MOISTURE CORN

	High Moisture Corn Plus Corn Silage	High Moisture Corn Plus Alfalfa Hay
No. steers	16	16
Starting weight	646	635
Final Weight	1034	1025
Daily ration (as fed)		
Corn silage	29.4	--
Chopped Alfalfa Hay	--	10.5
Corn	66.6	85.4
Supplement	4.0	2.5
Average daily gain	2.75	2.77
Average daily feed intake (air day)	19.9	18.6
Feed/lb gain (air day)	7.24	6.74

TABLE 7. SUMMARY OF 14 EXPERIMENTS COMPARING FEEDING VALUE OF HIGH MOISTURE VERSUS DRY GROUND EAR CORN**

Experiment Station	Year	Days on feed	Animals per lot	Percent Moisture*		Daily Gain (lb.)*		Lbs. Concentrate per 100 lb. gain*		Percent change from dry corn	
				HMC	DC	HMC	DC	HMC[a]	DC	Gain	Eff.
S.D.	1956	97	18	40	15	2.13	1.78	790	878	+19	+11
Ind.	1956	117	10	32	18	2.47	2.34	866	988	+ 6	+14
Ind.	1956	117	10	32	18	2.56	2.33	807	951	+10	+17
Ind.	1957	126	36	32	15	2.14	2.18	555	617	- 2	+11
Iowa	1957	119	36	31	15	2.98	3.05	675	750	- 2	+11
Iowa	1958	56	36	38	14	3.34	3.24	471	528	+ 3	+12
Ind.	1958	133	36	37	24	1.86	1.94	634	660	- 4	+ 4
Colo.	1958	112	8	53	14	2.41	2.52	433	483	- 5	+10
Mich.	1959	147	10	31	18	1.97	1.53	754	973	+29	+23
Colo.	1959	140	8	55	15	2.08	2.25	519	564	- 8	+ 8
Iowa	1959	175	6	30	14	2.12	2.31	726	805	- 8	+10
Iowa	1959	175	6	30	14	2.40	2.32	667	634	+ 3	- 5
Ohio	1959	119	21	36	12	2.15	2.04	685	803	+ 5	+15
Mich.	1960	203	13	23	19	1.65	1.60	734	725	+ 3	- 1
Average	14	131	18	36	16	2.30	2.24	663	740	+ 3	+10

[a]Corrected to same moisture content of dry corn.

*HMC = high moisture ear corn while DC = dry rolled corn

**Table reprinted form 1972 Iowa State University Report "Feeds for Beef Cattle"

TABLE 8. SUMMARY OF TRIALS WITH HIGH MOISTURE MILO

Storage Method	Trials	High Moisture as % of Dry Rolled Milo	
		Gain	Feed Efficiency
Acid treated high moisture milo	6	+8.8	+10.2
High moisture milo from air tight structure	11	+3.7	+11.1
High moisture milo ground and ensiled		-1.0	- 1.6

TABLE 9. RESEARCH RESULTS UTILIZING HIGH MOISTURE MILO STORED IN VARIOUS MANNERS

Ref & Storage Method	Length of Trial	Cattle/trt	Moisture of grain	Daily Gain	Feed/ Gain	HMM as % of DM Gain	HMM as % of DM Feed/Grain
Kansas (Fort Hays) - 1974							
Dry rolled milo	186	12	--	2.67	7.16	--	--
Acid treated	186	12	25.7	2.89	6.20	+8.2	+13.1
Acid treated	186	12	22.8	2.65	7.03	-.7	+1.8
Ground & ensiled (trench)	186	12	25.7	2.64	7.13	-1.1	+.4
Ground & ensiled (trench)	186	12	22.8	2.57	7.45	-3.7	-4.1
Kansas (Fort Hays) - 1975							
Dry rolled milo	144	13	--	2.75	7.88	--	--
Acid treated	144	10	24.3	3.19	7.27	+16.0	+7.7
Ground & ensiled (trench)	144	10	25.8	2.64	8.78	-4.0	-11.4
Ground & ensiled & acid treated	144	10	24.3	2.79	8.26	+1.5	-4.8
Kansas - 1972						HMM As % steam flaked	
Steam flaked milo	112	15	--	2.98	6.34	--	--
HM Air tight silo	112	15	29.0	3.18	6.48	+6.7	-2.2
HM Acid treated silo	112	15	29.0	3.16	6.80	+6.0	-7.3
HM Acid treated - metal bin	112	15	29.0	3.32	6.66	+11.4	-5.0
Rolled and ensiled	112	15	29.0	2.94	7.21	-1.3	-13.7
Kansas - 1973						HMM as % of DM	
Dry rolled milo	104	15	14	2.82	7.75	--	
HM Acid treated	104	15	24	2.95	7.38	+4.6	+4.8
HM Air tight silo	104	15	24	3.00	6.94	+6.4	+10.5
Kansas - 1975							
Dry rolled milo	92	15	14.5	2.32	9.66	--	--
HM Acid treated	92	15	27.4	2.80	7.91	+20.7	+17.9
HM Oxygen limiting	92	15	20.5	2.78	7.47	+19.8	+22.7
HM Ground & ensiled	92	15	26.4	2.60	9.08	+12.1	+6.0
HM reconstituted	92	15	26.7	2.62	9.12	+12.9	+5.6
Kansas - 1976							
Dry rolled milo	92	15		2.45	9.02		
Steam flaked milo	92	15		2.48	7.23	+1.2	+18.7
Air tight silo	92	15		2.68	8.35	+9.4%	+7.4
Rolled & ensiled	92	15		2.32	9.88	-5.3	-9.5
Reconstituted	92	15		2.45	9.41	0	-4.3

TABLE 9. RESEARCH RESULTS UTILIZING HIGH MOISTURE MILO STORED IN VARIOUS MANNERS -- cont.

Ref & Storage Method	Length of Trial	Cattle/trt	Moisture of grain	Daily Gain	Feed/ Gain	HMM as % of DM Gain	Feed/Grain
Iowa - 1975							
Dry rolled	208		13.8	2.73	6.59		
HM Air tight silo	208		23.6	2.60	6.38	-4.7	+3.2
HM Concrete stave silo	208		24	2.62	6.58	-4.0	+.2
Texas - 1973							
Dry rolled milo	120	50	--	2.24	8.45		
HM acid treated milo	120	50	28.0	2.33	7.11	+4.0	+15.9
Oklahoma - 1974							
Dry rolled milo	136	12	14	2.82	6.14		
Steam flaked milo	136	12	14	2.82	5.19	0	+15.5
HM - air tight silo	136	12	30	2.54	5.62	-9.2	+8.4
Texas - 1966							
Dry rolled milo	153	14	10	2.26	8.1		
Reconstituted milo	153	15	30	2.44	6.9	+8.0	+14.8
HM - airtight	153	15	Approx 30	2.31	8.1	+2.2	0
Texas							
Dry rolled	140	24	13	1.98	11.73		
HM airtight	140	24	Approx 30	1.96	9.96	-1.0	+15.1
Texas							
Dry rolled	154	15	13	2.29	13.32	+5.7	+12.6
HM airtight	154	15	Approx 30	2.42	11.64		
Texas							
Dry rolled	112	24	13	1.61	10.78	+2.5	+9.0
HM airtight	112	24	Approx 30	1.65	9.81		
Texas							
Dry rolled	140	24	13	2.13	9.15	-1.8	+9.0
HM airtight	140	24	Approx 30	2.09	8.33		
Oklahoma - 1967							
Dry rolled milo	174	12	--	2.23	7.6		
HM - airtight	174	12	31	2.58	5.78	+11.2	+23.9
Reconstituted	174	11	26	2.62	5.92	+17.5	+22.1

* HMM = high moisture milo while DM = dry rolled milo

MOISTURE CONTENT VERSUS INTAKE AND
ENERGY VALUE OF HIGH MOISTURE CORN

F. N. Owens and J. H. Thornton

Due to the marked influence of moisture content on high moisture corn (HMC) characteristics cited earlier by Thornton (this conference), animal performance results from 36 experiments at many different stations summarized by Corah (included in this publication) were plotted against moisture level of HMC. Dry matter intake and metabolizable energy (calculated back from intake, animal weight and rate of gain using the California net energy equations) of cattle fed HMC were compared to that for cattle fed dry corn (DC) in the same experiment. Percentage difference from DC was plotted against moisture level of the HMC. This comparison is presented in figures 1 and 2, and values from linear regressions within each storage system are given in table 1.

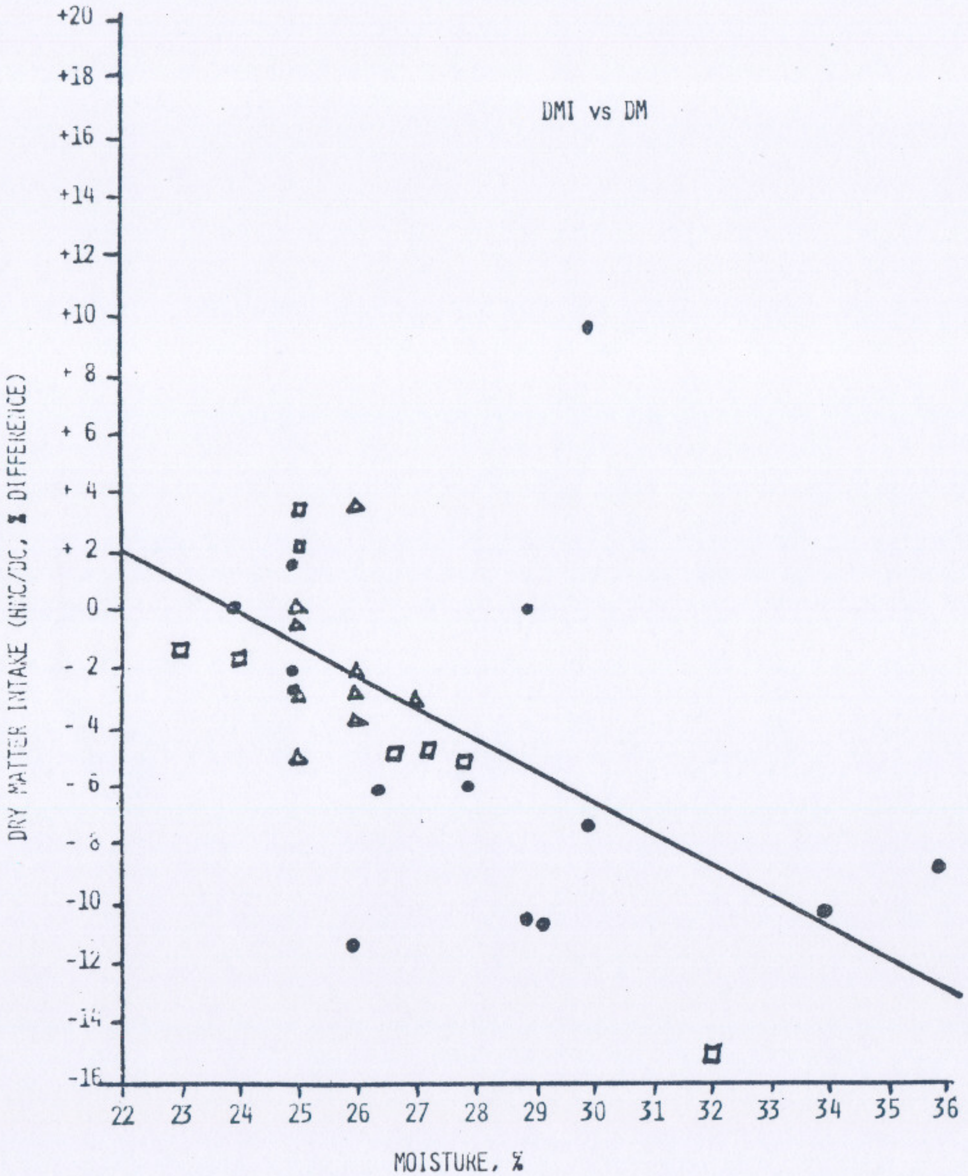
Regardless of storage type, metabolizable energy content of HMC increased with moisture content of HMC. On the average, energy value of HMC equaled DC at 23% moisture and increased by 0.3% for every 1% higher moisture. It is doubtful that errors in dry matter determination could explain all of this increase. Losses of energy after fermentation due to heating and handling would be expected to be greater with higher moisture content, so this could not explain the trend. Perhaps site or extent of digestion by the animal could be advantageous for higher moisture HMC.

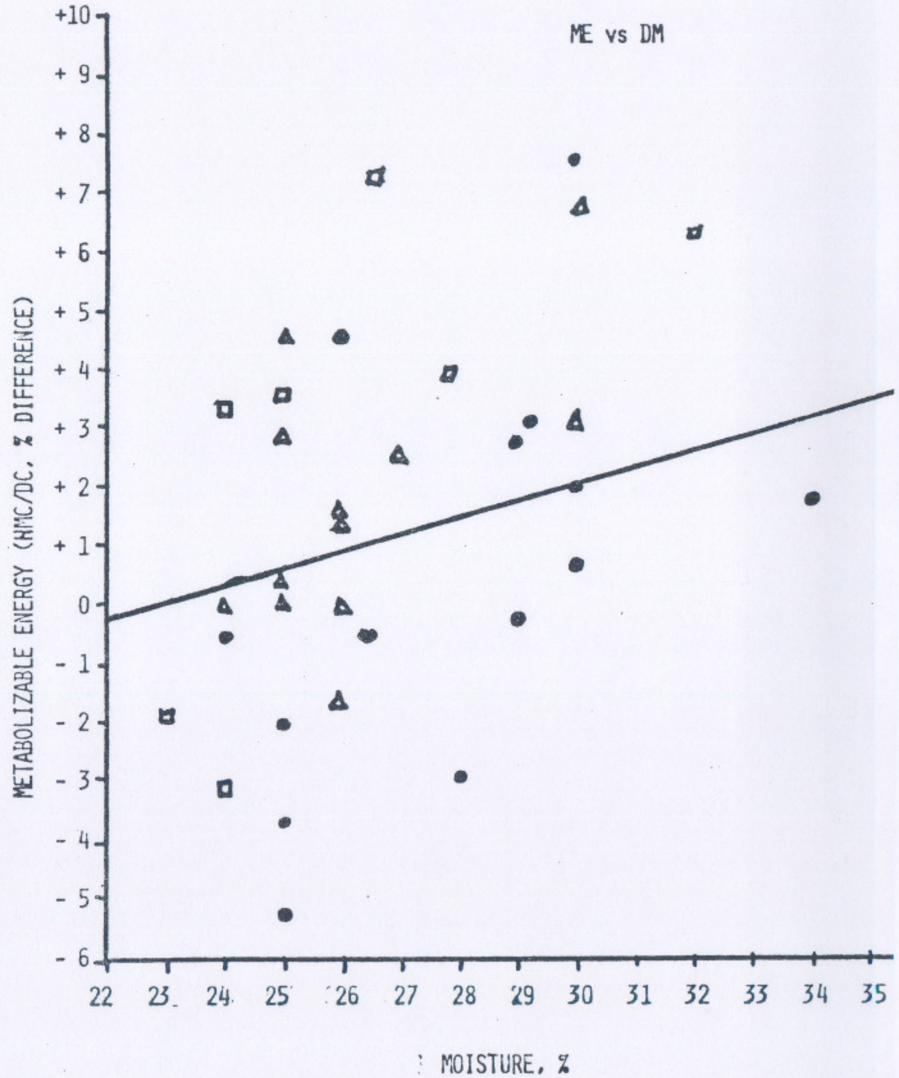
Dry matter intake of HMC and DC were equal, on the average, when HMC contained 24% moisture (or possible 23% moisture if 1% volatiles are lost during drying). For every 1% added moisture, intake decreased by about 1%. Intake decreased with moisture level across all methods of preservation, which should represent HMC containing different levels of soluble nitrogen and acid. Consequently, no explanation for depressed intake is apparent. Drier HMC should have an advantage in reduced fermentation energy loss and longer bunk life. This is at the expense of lower yields due to field loss, more feeding loss due to wind, and more oxidation and browning due to more difficult packing.

In summary, higher moisture levels will apparently maximize ME content of HMC but will also depress intake. The ideal moisture content depends on relative costs of feed and overhead or yardage. It is hoped that dry matter content will be reported in all published literature in the future.

TABLE 1. RELATIONSHIPS OF METABOLIZABLE ENERGY AND FEED INTAKE OT MOISTURE CONTENT OF HMC.

	Metabolizable energy			Dry matter intake		
	H_2O when HMC=DC	Change /1% H_2O	Reg.	H_2O when HMC=DC	Change /1% H_2O	Reg.
	%	% change	r	%	% change	r
Oxygen-limiting structures	22.7	+.76	.64*	24.5	-1.8	-.87**
Organic Acid preserved grains	24.4	+.91	.72**	24.7	- .96	-.55**
Conventional or bunker silos	27.6	+.26	.26	19.5	- .63	-.34
Overall summary	23	+.32	.30*	24	-1.01	-.56**


DMI vs DM
DRY MATTER INTAKE (HMC/DC, % DIFFERENCE)
+20
+18
+16
+14
+12
+10
+ 8
+ 6
+ 4
+ 2
0
- 2
- 4
- 6
- 8
-10
-12
-14
-16
22 23 24 25 26 27 28 29 30 31 32 33 34 35 36
MOISTURE, %


ME vs DM
METABOLIZABLE ENERGY (HMC/DC, % DIFFERENCE)
+10
+ 9
+ 8
+ 7
+ 6
+ 5
+ 4
+ 3
+ 2
+ 1
0
- 1
- 2
- 3
- 4
- 5
- 6
22 23 24 25 26 27 28 29 30 31 32 33 34 35
MOISTURE, %

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