High Moisture Corn With Additives For Cattle Finishing Diets

by

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Introduction

Commercial feedlots and farmer feeders who finish cattle for slaughter in the U.S. usually feed finishing diets containing a high proportion of cereal grains. Increasing energy prices have made the cost of drying feed grains at harvest more expensive, resulting in the widespread use of high moisture grains in finishing diets. Economically, high moisture corn (HMC) as a processing method compares favorably with the steam flaking method due to increased fossil fuel cost (Bull and Schake, 1980).

Orskov and Greenhalgh (1977) suggested the use of chemical processing of grains with alkali to enhance cereal grain utilization by ruminants. Orskov et al. (1979b) showed that barley grain processed with 35g/kg of sodium hydroxide (NaOH) was conserved for 6 mo at 74-83% dry matter (DM) without deterioration. Bothast et al. (1973) reported that the addition of ammonia to HMC had a preservative effect by reducing the microbiological population.

The addition of fermentation aids (i.e., inoculants and enzymes) to forages at the time of ensiling has produced varying results (Bolsen, 1978).

The purpose of this research was to determine the storage properties and feeding values of additive treated, chemically treated, and conventionally processed HMC. Beef cattle and lambs were used for measuring the feeding values.

Methods of Dry Matter Determination

Dry matter (DM) is commonly determined by measuring the weight loss during oven drying with the increased weight loss assumed to be water and the residue assumed to be DM. Oven drying is advantageous because limited equipment is necessary, it is rapid, and the investment and operating costs are low. However, DM of fermented feeds is usually underestimated due to the loss of volatile, energy-containing compounds during oven drying (Goodrich and Meiske, 1971). The underestimation of DM by oven drying results in an overestimation of nonvolatile components of the feedstuff such as crude protein and minerals. The true total DM required for animal weight gain (feed required for gain) is underestimated; therefore, many feed efficiency data reported in the literature are in error (Jones and Larsen, 1974; Clancy et al., 1977; Fox and Fenderson, 1978).

Levy, as reported by Clancy et al. (1977), observed a value for toluene distillation determination of DM in feces from young dairy steers which was 12.76% greater than that for forced air drying at 80 C. Differences for DM may have been large due to added non-protein nitrogen (NPN) in the concentrate diet, possibly giving high ammonia and ethanol in the feces. Aerts et al. (1974) determined DM on 31 samples of feces (18 obtained from cows and 13 from wethers fed different rations) by several procedures and concluded that the errors in DM determination for oven drying at 70 C were 1.22%. They suggested, however, that the feces from animals on higher feed intakes would have errors in DM that were greater than 1.22%. This difference may be related to a higher rate of passage and reduced resorption of volatile substances in animals that are receiving diets at intake levels above maintenance.

The effect of oven drying temperature (40, 70, and 100 C) was investigated using silage by Minson and Lancaster (1963). Drying silage at 40 and 70 C reduced the apparent loss of volatiles but did not alter the magnitude of the difference among the samples.

Alternatives to DM determinations by oven drying have been suggested by Fischer (1935), the Karl Fischer titration; Hoffman, as mentioned by Fetzer (1951), distillation; McCormick (1970), saponification; and Yao (1979), alcohol extraction and gas-chromatography.

The Karl Fischer method (Fischer, 1935) is a direct method for determining water which has been applied to grain (Hart and Neustadt, 1957), silage and feces (Olafsson and Warner, 1977). However, the method is operator dependent for accurate titrations, expensive, and has an objectionable smell.

Numerous distillation methods for DM determination have been used (Dewar and Mc Donald, 1961; Fenner and Barnes, 1965). Corrections are necessary with distillation methods to adjust for volatiles (e.g., ethanol, acetic acid, and ammonia) that are extracted with the distillate (Dewar and McDonald, 1961; Brahmakshatriya and Donker, 1971).

The saponification reaction and the determination of DM, as outlined by Mc Cormick and Tu (1970) and adapted by Hood et al. (1971), is a direct chemical measurement of water. Problems with this technique, as viewed by Fenton et al. (1981), are that precision is not equal to oven drying; sodium metal is required; it is difficult to use; and, anhydrous conditions must be maintained.

The DM determination method of Yao et al. (1979) and Fenton et al. (1981) using methanol extraction in conjunction with gas-liquid chromatography is a relatively new technique. This method, presently, seems of most value for routine laboratory use because it lends itself to automation, is rapid, and is not as operator dependent as the Fischer determination of DM.

Effects of Dry Matter on Ensiled High Moisture Corn

Several characteristics of ensiled HMC are related to DM including pH, lactic acid, and soluble nitrogen. As DM of HMC decreases, the pH declines and the lactic acid concentration increases. Soluble nitrogen levels increase as the DM of HMC decreases and the relationship between soluble nitrogen and soluble NPN is close. Approximately 90% of the soluble nitrogen may be NPN. In vitro DM disappearance of ensiled grain showed that drier grain had the lowest DM disappearance following 21 h of incubation (Thornton el al., 1977). Thornton et al. (1978) compared digestibilities of two HMC at two DM levels, 70 and 77%. The HMC at 77% DM had lower DM and starch digestibilities and produced three times more fecal starch than HMC at 70% DM. This is in agreement with earlier comparisons (Owens and Thornton, 1976) across DM levels of corn. The energy value of HMC equaled dry corn at 77% DM and for every 1% decrease in DM content, the energy value increased .3%. The trend toward higher efficiency of nutrient utilization when HMC is compared with dry corn may be associated with the method of determining the DM content of the ensiled grain. Jones et al., (1971) reported that estimation of the DM content of acid treated HMC using standard drying procedures can result in an underestimatation of DM content by as much as 6%. In addition, DM losses do not necessarily correlate in a positive manner with energy losses for ensiled grains (Owens and Prigge, 1975; McDonald, 1981).

NaOH Treatment of Cereal Grains

Recently, a new method for processing cereal grain was proposed by Orskov and Greenhalgh (1977) and Orskov (1979). This method involves the alkali (NaOH) treatment of grain prior to feeding in an effort to improve digestibility, reduce rumenitis from excessively processed grain, and alleviate depressed cellulose digestion when grains are fed with roughages.

Nylon Bag Evaluations: The effects of NaOH processing on grain digestibility were tested, initially, by incubating 5 g samples of barley grain in dacron bags in the rumen of sheep (Orskov and Greenhalgh, 1977). Rate of barley digestion was measured by DM disappearance from the dacron bags. After 24 h of incubation, digestion was increased by NaOH processing compared with whole, unprocessed barley. It was concluded that a level of 35 g NaOH/kg of air dry grain was optimum. Orskov et al. (1978) used the same dacron bag technique and showed that NaOH processing increased the rate of DM disappearance compared with whole barley but decreased the rate of disappearance compared with rolled barley. These researchers hypothesized that the inhibitory effects of grain diets on ruminant voluntary intake of roughages would be reduced when fed NaOH processed grains rather than grains conventionally processed by roller mills. They concluded that the slower rate of substrate release from NaOH processed grain was less inhibitory on the activity and number of cellulolytic bacteria in the rumen. Sriskandarajah et al. (1980) also showed that dacron bag disappearance rates of rolled barley were much more rapid, initially, than those of NaOH processed barley, but the final disappearances at 36 h were similar for barley processed with 3% NaOH and rolled barley. In contrast, Anderson and Berger (1979b) reported that the DM disappearances for corn grain from nylon bags incubated in the rumen for 24 h were: whole dry corn, 3.89%; whole HMC, 11.47%; 3% NaOH processed whole HMC, 33.80%; and 6% NaOH processed whole HMC, 81.17%. The

effect of diet on ruminal fiber (cotton thread) digestion using nylon bags identified NaOH grain processing as a favorable environment for fiber digestion.

Yauk et al. (1979) reported that the greatest increase in pepsin digestibility and in vitro disappearance were noted with whole sorghum grain compared with ground sorghum grain when processed with 1, 2, or 4% NaOH and stored 10 d prior to analysis. They suggested this was due to increased seed coat disruption.

Digestion Trials: Orskov and Greenhalgh (1977) found the difference in digestibility of DM between rolled (78.9%) and NaOH processed barley (75.2%) was not significant while the whole unprocessed barley (67.2%) was the least digestible. These researchers used Friesian steers fed ad libitum and barley processed with 35 g NaOH/kg. Orskov et al. (1978) compared several processing methods to the 35 g NaOH/kg grain for barley and found that the DM digestibilities for whole, NaOH treated, torrified (infra-red heat treated), or crimped barley were 672, 807, 813, and 834 g/kg, respectively, when fed to cattle. In continued investigations, Orskov et al. (1979a) reported that lamb digestibilities of organic matter by lambs were: 81.4, 77.2, 82.1, 79.1, 79.0, and 80.1% for whole barley fed ad libitum which had 11, 14, 17, 20, 23, 23% moisture, respectively. The 4th and 5th grains were processed with propionic acid and the 6th grain was processed with 20 g/kg of NaOH added as a 30% solution.

Orskov et al. (1980) used incremental additions of NaOH (1, 15, 30, 45 g/kg air dry weight) on wheat, oats, and maize; and higher levels (15, 35, or 45 g/kg) on barley. In digestion trials with Friesian steers, the organic matter digestibility was increased by NaOH processing from 61 to 83% for barley, from 61 to 76% for oats, from 83% to 89% for maize, and from 79 to 92% for wheat. The optimium levels (g of NaOH/kg air dry grain) suggested by these authors were 30-35 for barley, 45-50 for oats, and 25-30 for maize and wheat. The low level of NaOH (15 g/kg) applied to oats seemed to reduce digestion compared to the untreated grain.

Recently, Anderson and Richardson (1981) reported processing sorghum grain by the

following methods: 1) dry ground; 2) reconstituted and rolled; 3) NaOH processed and rolled; and 4) NaOH processed and fed whole. Lambs were fed a complete diet containing approximately 80% sorghum grain and DM digestibilities of the four diets were: 74.4, 74.0, 70.5, and 70.2%, respectively. The level of NaOH processing was not reported.

Feeding Trials Using NaOH Processed Grains: In 1978, Orskov et al. measured the voluntary intake of ryegrass hay fed to steers when supplements of barley were fed in the following processed forms: 1) whole unprocessed, 2) NaOH processed (35 g/kg), 3) torrified, 4) crimped, 5) rolled, 6) ground and, 7) ground and pelleted. The daily barley supplements were fed at 50 g/kg of live weight$^{0.75}$. The voluntary intakes of hay DM were: 42.1, 43.0, 38.1, 35.1, 34.9, 34.4, and 30.5 g/kg of wt$^{0.75}$/day, respectively. These authors concluded that NaOH processed barley would ensure both efficient digestion of barley and a high intake of hay. In further research, Orskov and Reid (1979) fed 16 mid-lactation Friesian cows diets of rolled barley or NaOH processed (35 g/kg) barley. Two levels of barley (70% or 80% of the diet) were fed. For both dietary levels of barley the cows fed NaOH processed barley had a greater molar proportion of acetic acid in the rumen, a higher percentage of fat in the milk, and a slightly greater production of fat corrected milk compared with the cows fed rolled barley.

Orskov et al. (1979a) and Orskov et al. (1979c) observed a slight depression in gain for lambs fed NaOH processed barley compared with whole barley; however, feed conversions were equal. NaOH processed oats showed improvement in both carcass weight gain and feed efficiency compared with whole oats fed to lambs. Steers fed rolled barley had more rapid liveweight gains and required less feed per unit of gain than those fed NaOH processed barley. Steers fed NaOH processed oats or rolled oats gained similarly but steers fed NaOH processed oats had better feed to gain ratios.

Bettenay (1980) conducted a trial with 28 cows individually fed over a 10 week period to compare the value of rolled barley sprayed with a caustic soda (NaOH) solution (35 g/kg air dry grain). Chemical treatment of the barley had no advantage for yield or

composition of milk or liveweight gain. Feed intake was higher initially for the NaOH processed barley, but the higher intake did not persist beyond the second week.

Barley processed with NaOH at 30 g/kg of grain was fed to lactating dairy cows grazing kikuyu grass (Sriskandarajah et al., 1980). Milk production was higher and liveweight gain lower for cows fed NaOH processed barley than for those fed rolled barley. The suggested mechanism leading to greater milk production and hay intake for cattle fed NaOH processed whole barley was a slower rate of digestion for the chemically processed barley. In a second experiment, yearling steers were fed grass hay ad libitum with NaOH processed barley (NaOH 30 g/kg) or rolled barley. Hay intake was higher ($P<.05$) for the NaOH processed grain; however, in vivo digestible organic matter was 65% for rolled barley diets and 60% for NaOH processed barley diets.

Anderson and Richardson (1981) fed sorghum grain to growing lambs in a feedlot trial and compared: 1) dry ground, 2) reconstituted and rolled, 3) NaOH processed and rolled, and 4) NaOH processed and fed whole. Eighty-four day means for average daily feed intake (kg), average daily gain (kg) and feed efficiency (F/G) for treatments 1, 2, 3, and 4, respectively, were 1.18, .192, 6.30; 1.09, .177, 6.56; 1.09, .176, 6.35; and 1.13, .183, 6.36. There were no differences among treatments. These results are different from the report of Anderson and Berger (1979a) using cattle and comparing: 1) whole shelled corn (WSC), 2) whole high moisture corn (WHMC), 3) rolled HMC, 4) NaOH processed WSC, and 5) NaOH treated, rolled HMC. There were no significant treatment effects on daily DM intake; however, cattle receiving the NaOH processed corns had lowest average daily gains and poorest feed efficiencies.

Innes et al. (1981) reported that steers fed NaOH processed barley had the same rate of gain as steers fed rolled barley when both treatments were fed with 50% silage on a DM basis. However, Hall (1981) feed lucerne hay ad libitum and barley supplements (NaOH processed at 36 g/kg of whole barley, propionic acid treated rolled barley, or dry rolled barley) at several levels. Results indicated that animals receiving NaOH processed

whole barley had higher fecal starch levels (119 to 298 g/kg of DM for NaOH vs 32 to 75 g/kg of DM for propionic acid treated or dry rolled barley). The estimated percentage of whole grain contained in the feces was the highest for NaOH processed barley.

Rumen Turnover and Rumen Volatile Fatty Acid Concentrations: The effects of sodium additions to the ruminant diet on volatile fatty acids (VFA) concentrations in the rumen are not well defined. Ololade and Mowat (1975) found acetic acid concentrations decreased and butyric acid concentrations increased with increasing levels (0 to 4.0%) of NaOH fed to wethers in 50% barley straw; 50% barley grain diets. However, other researchers have found trends for acetic acid concentrations in the rumen to be higher for NaOH processed diets (Hemsley, 1975; Orskov et al., 1978; Thomson et al., 1978; Rogers et al., 1979; Orskov and Ried, 1979; Sriskandarajah et al., 1980). Increasing acetic acid values have been observed by Roger and Davis (1980) using mineral salts of $NaHCO_3$ or NaCl with constant infusion into fistulated Holstein steers. They observed that as the total fluid outflow from the rumen increased; the total volatile fatty acid concentration decreased molar percent acetate increased, and molar percent propionate decreased. Concentrations (mol/d) of acetic acid were relatively constant, propionic acid decreased, and butyric acid increased slightly.

Potter et al. (1972) found that the provision of saline drinking water to sheep increased the dilution rate of a soluble marker in the rumen and Hemsley (1975) reduced the mean residence time in the rumen of a soluble marker from 20 h to 12 h in wethers with the addition of sodium chloride. The reduced rumen retention times associated with NaOH additions to low quality roughages (Combe et al., 1979; Berger et al., 1980) has prompted a possible explanation for the discrepancy between increased in vitro digestion but decreased live animal performance with NaOH processed roughages (Berger et al., 1980; Berger et al., 1981; Horn et al., 1981).

Carcass Composition: Carcass composition has been altered in 2 y old wethers fed alfalfa hay and provided a solution of 1.3% NaCl in the drinking water (Walker et al.,

1971). Wethers receiving the NaCl water had less carcass fat, being largely replaced by water and to a lesser extent by protein, and the composition of their fat tended to be less saturated compared with wethers receiving no NaCl. Further investigations (Potter et al., 1972) have suggested that these carcass changes are due to nutrient composition changes at the small intestine, resulting from osmotic pressure and rate of turnover changes in the rumen.

Storage Properties: Flipot et al. (1975) using laboratory silos and shelled HMC showed a reduction in soluble nitrogen with the addition of 1.5% NaOH. Reduced soluble nitrogen fractions were also reported by Flipot el al. (1975) for ensiled alfalfa and whole plant corn silage processed with NaOH. However, Yauk et al. (1979) found that the percentage of nitrogen soluble in buffer solution and the NPN as a percent of soluble nitrogen increased with the addition of NaOH to sorghum grain when applied at 1, 2, or 4% of the DM and stored 10 days.

Orskov and Greenhalgh (1977) reported that barley processed with NaOH and stored at 81% DM for 6 mo showed no deterioration. Orskov et al (1979b) confirmed the improved storage qualities for up to 4 mo for NaOH processed high moisture grain; however, ambient storage temperatures ranged from 3 to 17 C. Bettenay (1980) observed that barley processed with a 30% solution of caustic soda (35 g NaOH/kg of air dry grain) stored well for at least 3 weeks. Barley was moved a few h after NaOH application to prevent compaction.

Ammonia Treatment of High Moisture Grain

Bothast et al. (1973), following the lead of research conducted with citrus, demonstrated the feasibility of using ammonia as a fungicide for shelled corn. Corn was tempered to 74% DM at 25 C for 24 h with sterile water and .5 or 2.0% ammonia (w/w) was added as ammonium hydroxide to bring the final DM to 70%. The ammonia treatments eliminated molds and yeasts with a trend to reduce bacterial counts. Molds killed were species of Aspergillus, Penicillium, Fusarium, Trichoderma and Rhizopus. Britt and Huber (1975) added several sources and levels of NPN (including aqua ammonia) to corn silage and found no observable differences among treatments and control in species or relative proportions of fungi after 86 d of fermentation and storage. However, at d 86 control and urea treatments had lower total fungal colonies than NH_3 treatments. The addition of .45% or more of ammonia N inhibited lactic acid production and was associated with higher fungal counts before the experimental silos were opened.

Bothast et al. (1975b) made a microbiological evaluation of HMC (73% DM) treated with .48% ammonia as a 22% aqueous solution. In general, microbial growth proceeded at a slower rate and was restricted initially to bacteria. A mold, Scopulariopsis brevicaulis, was isolated from ammonia treated HMC (Bothast et al., 1975a) during preservation studies and it was found to grow readily at the higher pH associated with ammonia additions. This mold efficiently converts ammonia to mold organic material with a loss in corn DM. Dalmacio and Fung (1977) showed that the application of 1.0 or 1.5% ammonia (Cold-flo process) reduced initial bacteria counts of whole corn having 72 and 78% DM. However, during 6 mo of storage, the surviving bacterial population multiplied. Mold growth was eliminated initially by the application of 1.0, 1.5, and 2.0% ammonia and reduced by the application of .5% ammonia. During storage for 6 mo mold counts increased, reaching 10^{10}, 10^8, and 10^8 colony forming units (CFU) per g for cracked corn

and 10^{10}, 10^{6}, and 10^{6} CFU per g for whole corn at .5, 1.0, and 1.5% ammonia, respectively. The 2.0% ammonia treatment was the best suppressant of mold growth with 10^{3} CFU after 6 mo. No recoveries of ammonia following storage were reported.

Srivastava and Mowat (1980) showed that an application of 2% ammonia gas essentially eliminated fungi and yeasts during storage in sealed 205 l drums for a period of 60 d. The number of bacteria were markedly reduced but not eliminated. This agrees with the earlier results of Peplinski et al. (1978) using larger quantities of grain which were stored indoors for a 14 mo period.

Aflatoxin inactivation: Ammonia treatment of corn has been used to detoxify grain infected with the harmful secondary metabolite, aflatoxin, produced on corn by widely distributed strains of two common molds, Aspergillus flavus and A. parasiticus (Brekke et al., 1977a). In their studies the inactivation of aflatoxin using ammonia was highly temperature sensitive over the range -18 to 60 C and became more effective as the corn DM was decreased from 87.5 to 80%. Extensive inactivation required progressively more time. Reduction of residual aflatoxin content to a acceptable levels became more difficult as initial aflatoxin level increased. Ammonia was added at levels of .5 to 3.0% on a DM basis. These results showing that ammonia will detoxify aflatoxin, has been confirmed by further studies (Brekke et al., 1977b; Williams II and Norred, 1978; Nofsinger and Anderson, 1979; Brekke et al., 1979; Southern and Clawson, 1980).

Corn Discoloration and Lipid Alteration: One readily observable characteristic of ammoniated corn is its change in seed coat color. White corn develops a yellowish or tannish color and yellow corn develops a color ranging from slight discoloration to a dark tan or mahogany color. The extent of this response is dependent upon reaction conditons, such as the level of added ammonia, corn DM, reaction temperature, and reaction time (Brekke et al., 1977a). The ammoniated pigments are largely water soluble because much of the original color returns upon soaking the corn in water. A more intense study of ammonia and corn reactions was investigated by Black et al. (1978) with the discovery

that corn lipids, particularly 18:2 and 18:3, in the presence of oxygen form a nitrogenous derivative that is unextractable with the usual fat solvents.

Recovery of Ammonia: Lancaster et al. (1974) applied .48% ammonia as a 22% aqueous solution to 52860 l of freshly harvested HMC (DM not reported) as a coarse spray at the boot end of an inclined auger. Total ammonia recovered, as sampled at the auger exit, averaged 81% of that applied.

Britt and Huber (1976) treated 73% DM shelled corn with an 22% aqueous ammonia solution to provide .54% anhydrous ammonia. Nitrogen recovery averaged 44.6% for the aqua-ammonia treatment on d 1 but the losses may have been due to miscalculations in flow rates or ammonia volatilization. There was no decrease in nitrogen during the 90 d storage in gravity wagons. In a second trial 54% of the added nitrogen was recovered when whole HMC (75% DM) was treated with 1% aqua-ammonia spray and stored for 100 d in small concrete stave silos.

Recently, Srivastava and Mowat (1980) reported a 35% loss of the retained ammonia as free gas. The 72% DM whole HMC had been treated with 2% anhydrous ammonia and stored in barrels lined with plastic bags. In a field study made by Peplinski et al. (1978), ammonia was added to corn by the aqua procedure and as a gas. Recovery of nitrogen indicated that 78% of the added nitrogen was lost during 410 d of storage.

Urea additions to HMC can lead to a large percent of the urea being hydrolyzed to ammonia (Schmutz et al., 1964) and losses of this added nitrogen ranging from 4 to 23% (Dutton and Otterby, 1971).

Storage Characteristics: Ground HMC was treated with aqua-ammonia at levels of 0, .1, .15, .2, .3, .4, .6, .8 and 1.2% ammonia (dry basis); stored in .95 l glass jars; and allowed to ensile for 7, 14, 28, or 56 d (Thornton et al., 1977). Treatment with levels of .1 to .4% ammonia increased total fermentation as measured by lactic acid production; whereas, levels of .6% ammonia or higher restricted fermentation as indicated by negligible levels of lactic acid and elevated pH. All levels of ammonia reduced

solubilization and degradation of corn protein at 56 d after ensiling.

Whole HMC (72% DM) that had been treated with aqua-ammonia developed a moisture gradient following 60 d of storage in a 2.4 m long x 1.8 m wide x 2.4 m high closed plywood bin (Peplinski et al., 1978). Moisture was greatest at the bin top compared with the lower levels and the difference ranged from 1 to 7% over the last 134 d of storage. Montgomery et al. (1980) described the addition of gaseous ammonia, aqua-ammonia, or methylene-bis-propionate (MBP) to HMC quantities in excess of 9090 kg. In these field studies neither gaseous anhydrous ammonia or MBP treated corn developed a moisture gradient over the 6 mo storage period. The aqua-ammonia treated corn was stable through 4 mo of storage; however, during the 5th mo of storage an area of increased moisture with microbial activity was visually observed at the top center of the grain mass.

Whole HMC treated with aqua-ammonia stored for 410 d, as reported by Peplinski et al. (1978), had a DM loss of 14% compared with corn stored dry.

In Vitro and Nylon Bag Digestibilities: Muhrer et al. (1979) showed that the addition of 1.5% anhydrous ammonia to 82.5% DM whole corn did not alter the in vitro DM digestibility when compared to untreated corn. However, incubation in rumen fluid media containing ammoniated corn or ammoniated corn plus starch had significantly lower levels of free ammonia (at 2 to 8 h) than mixtures containing isonitrogenous amounts of untreated corn grain plus NH_4HCO_3. The largest amount of soluble protein was found in incubations containing ammoniated corn. In addition, the susceptibility of the grain to a starch hydrolyzing enzyme was increased when the grain was ammoniated. In contrast, Srivastava and Mowat (1980) found that the rate of starch degradation by amyloglucosidases decreased with increasing levels (1, 2, or 3% DM basis) of ammonia. Also, incubation of ground corn in nylon bags placed in the rumen of steers indicated slower rates of DM disappearance with the higher levels of anhydrous ammonia. Contrary to ground corn, whole corn treated with ammonia and incubated in the rumen by the

nylon bag technique had a much faster rate of disappearance than non-treated whole corn. These researchers also observed that with 2% addition of anhydrous ammonia, 35% of the added nitrogen was retained following exposure to air. Only 56% of this nitrogen was solubilized by rumen fluid but all of the added nitrogen was pepsin soluble. This agrees with the data of Peplinski et al. (1978) showing that 25% of the added and retained nitrogen reacted with corn to form products other than free ammonia.

Digestion Studies: Digestion studies using steers have shown no improvement in the digestibility of DM for diets containing ground HMC or whole HMC treated with ammonia compared with diets containing urea. The nitrogen fractions of corn treated with ammonia were similar to urea as sources of dietary nitrogen (Britt and Huber, 1976; Saenger et al. 1981). In a digestion study with lambs, Lalonde et al. (1975) fed several diets containing ammonia treated corn silage and/or ammonia treated HMC. There were trends shown for higher fiber digestibilities with ammonia treated corn silage or ammonia treated HMC.

Feeding Trials: Britt and Huber (1976) reported two short feeding trials using 24 lactating dairy cows fed for 5 wk in trial one and 16 dairy heifers fed for a 58 d growing period in trial two. The first trial used 73% DM corn treated with aqua-ammonia to add .54% anhydrous ammonia and the HMC was stored for 90 d; in the second trial, 75% DM corn was treated with 1% aqua ammonia and stored for 100 d. Lower milk yields in trial 1 were reported for the ammonia treated HMC compared with HMC treated with 1% propionic acid; alfalfa haylage fed ad libitum served as a source of additional nitrogen for both treatments. It was suggested that because the ammonia treated grain showed extensive molding, milk production may have been reduced due to toxins present in the corn. In trial 2, ammonia treated corn maintained significantly higher mold counts than propionic acid treated corn; however, heifer performance was slightly better for the ammonia treated HMC.

Montgomery et al. (1980) described a feeding trial in which 42 steers weighing 308

kg were assigned to one of three HMC (76-78% DM) treatments where additions were made on a DM basis: 1) gaseous ammonia, .9%; 2) aqua-ammonia, 1.3%; or 3) methyl-bis-propionate (MBP), .8%. In the 86 d growing trial average daily gains and feed efficiencies favored the ammonia treatments over MBP; although, the MBP was the best preservative based on growth prevention of microorganisms. Recent research in Norway by Laksesveia and Slagsvold (1980) and Laksesvala (1981) has shown increases in the digestibility of low or high DM barley treated with ammonia when fed to sheep.

Microbial and Enzyme Treatments of High Moisture Grain and Forage

A number of products classified as "aids to fermentation" are available commercially for addition to forage and grains at the time of ensiling. The function of such aids is to alter the rate and/or enhance the efficiency of fermentation. It is the objective of such additions to retain a higher proportion of one or more nutrients in the silage DM. This group of additives includes bacterial and yeast inoculants, enzymes, flavors, and antioxidants. Research results published on the use of these fermentation aids have been variable and inconsistant (Bolsen, 1978; Thomas, 1978).

"Silo-Best" is a microbial preservative containing the dried fermentation products from Aspergillus oryzae, Bacillus subtilis and Lactobacillus acidophilus (Hendrix, 1980). Direct-cut alfalfa silage treated with Silo-Best was similar to control silage for visual spoilage and DM loss (Krause and Clanton, 1977). Steers fed treated silage gained .12 kg/d more and required .43 kg less DM/kg of gain than steers fed untreated silage. Krause and Britton (1980) treated first cutting alfalfa silages (wilted to 32% DM) with Silo-Best and found steers fed treated silage gained 11% faster and were 6.6% more efficient than steers fed control alfalfa silage. Treated silages had less acetic and propionic acids than control silage; however, lactic acid levels were similar. More soluble nitrogen was present and pH was lower in treated silage.

Research using corn silage treated with Silo-Best and fed to steers (250 kg initial wt) with either alfalfa or soybean meal as protein sources was reported by Krause and Britton (1980). When fed soybean meal, steers receiving the treated silage diets had equal gains but were 4% more efficient in DM conversion compared with steers fed the untreated silage diets. Alfalfa supplemented silages showed a 4% increase in gain and 6.5% more efficient feed conversion for the Silo-Best treated corn silage compared with control corn silage.

Burghardi et al (1977) reported similar weight gains and feed conversions between untreated and Silo-Best treated corn silages using urea as the supplemental nitrogen source. Bolsen and Riley (1980) found that DM preservations were 80.9 vs 87.5%, weight gains were 1.11 vs 1.17 kg/d and feed conversions were 7.67 vs 7.45 kg of DM/kg for untreated and Silo-Best treated corn silages, respectively. In another trial Bolsen and Ilg (1982) showed corn silage treated with Silo-Best to have improved feed efficiency ($P<.05$) compared with control silage. Dry matter losses during fermentation, storage, and feedout from concrete stave silos were similar for the control and Silo-Best (10.25%) corn silages; however, DM losses were reduced with the use of Silo-Best in experimential silos and nylon bags buried within the stave silos. Young et al. (1979) reported improved feed conversion for yearling steers fed ensiled HMC treated with Silo-Best compared with untreated ensiled HMC.

Burghardi et al. (1980) used a commercial additive (not identified by name) that contained Bacillus subtilis, Lactobacillus acidophilus, Aspergillus oryzae, and mixed lactic ferment enzymes. Corn silage treated with the product did not improve the feedlot performance of steers or silage digestibility in lambs. In addition the authors evaluated microbial treated corn silage in laboratory silos using two levels of each of the following organisms: L. bulgaricus, L. acidophilus, L. brevis, Streptococcus lactis, S. cermoris, and Aspergillus oryzae. The conclusion based on these trials was that microbial additions to properly ensiled grain silage were of questionable value in terms of nutrient preservation. This agrees with the work of Black et al., (1980); Thonney et al., (1980); Moon et al., (1981); and Ely et al., (1982). Although Ely et al. (1981) showed some beneficial effect on nutrient recovery in alfalfa and wheat silages treated with L. plantarium. Buchanan-Smith and Yao (1981) have shown that lactic acid bacteria and/or hydrolytic enzymes with an antioxidant were not effective fermentation aids to alfalfa silage; whereas, added glucose resulted in a more desirable fermentation.

Rust et al. (1978) compared five commerical silage additives for corn silage and

reported that preservation was improved, fermentation altered, and feed intake and gains in lambs improved slightly when compared with control corn silage. However, these same additives had little effect upon the fermentation characteristics of HMC or its acceptabiltiy by growing lambs (Owens et al., 1979).

Heidker et al. (1982) fed steers lactobacillus inoculated ensiled high moisture sorghum grain and found slaughter cattle feed conversions were improved with the addition of the inoculant. However, Heidker et al. (1983) found no improvement in cattle performance or aerobic stability of high moisture sorghum grain when a silage additive containing lactobacillus and an antioxidant were incorporated with ground high moisture sorghum grain at ensiling.

Aerobic Deterioration of Silages

The aerobic deterioration of silage is a microbiological process in which carbohydrate is oxidized to form water with a loss of DM as carbon dioxide and the production of heat. If glucose were the substrate oxidized, the chemical formula would be as follows:

$$C_6H_{12}O_6 + 6\ O_2 \quad \text{yields} \quad 6\ CO_2 + 6\ H_2O + \text{Heat}$$

By definition the use of oxygen makes this chemical reaction aerobic and not anaerobic; therefore, terms that refer to silage deterioration in the presence of oxygen as "secondary fermentation", "refermentation", or "after fermentation" are inappropriate as fermentation is an anaerobic process.

The significance of deterioration is measured in terms of loss of nutrients which are a monetary loss to the owner of the silage. Aerobic deterioration is of minor consequence during periods of low ambient temperatures or when daily surface removal of the ensiled mass is sufficient. High ambient temperatures coupled with slow or delayed surface removal of silage may result in large nutrient losses, low nutrient availability, and reduced silage acceptability. However, not all silages are susceptible to aerobic deterioration and these stable silages have a very limited temperature rise and a negligible DM loss.

The following discussion has three objectives: 1) to review the chemical characteristics of silage at the end of anaerobic fermentation and to identify those that may make the silage stable , 2) to discuss the general microbiological events which bring about deterioration, and 3) to discuss the characteristics measured as indicators of

aerobic deterioration.

I. Chemical Characteristics Of Silage That Affect Its Stability Following Anaerobic Fermentation

Several chemical characteristics have been associated with silages that are stable on exposure to oxygen; however, these associations are often more indirect than direct measures of stability. In general, clostridial silages are more stable in the presence of oxygen than are well preserved lactic acid silages and this stability has been attributed to higher VFA concentrations such as acetic, butyric, isovaleric, and caproic. Ohyama et al. (1975), found no aerobic deterioration in Italian ryegrass silage containing more than .5% butyric acid and in a survey of 50 grass silages Ohyama et al. (1980a) concluded that high butyric acid content was related to stability. Barry et al. (1980) ensiled crops of ryegrass/clover, lucerne, and oats using formaldehyde-containing additives and found little aerobic deterioration occurred in silages containing 2.5% (DM basis) or more butyric acid and inconsistant stability when the levels of butyric were 1.0 - 2.5% of the DM.

Henderson et al. (1979) in studies on the aerobic stability of commercial silages in Scotland, found silages that contained butyric acid were stable and explained that the two butyric silages that were unstable also had only trace amounts of valeric and caproic acids (less than .16% of the DM). The stable butyric silages had valeric acid levels of .31 to .42% and caproic acid levels of .29 to .86% of the DM. Although the authors did not discuss the propionic acid levels, the more stable butyric silage had nearly twice the amount of propionic acid compared with the less stable silages. However, in all silages

propionic acid did not show a correlation with any of the deterioration characteristics measured. This is in agreement with results of Ohyama et al. (1975) who found that, although silages with no propionic acid were more susceptible to deterioration, some were unstable even at high propionic acid levels. Crawshaw et al. (1980) showed that yeast appeared to flourish at application rates of propionic acid below 7 liters per ton even though growth of bacteria and mold were restricted.

Henderson et al. (1979) showed a positive correlation in stability of silages with ammonia nitrogen values. They concluded that ammonia nitrogen is derived mainly from deamination of amino acids through clostridial action resulting in the formation of higher VFA such as n- and iso-valeric and n- and isocaproic. It is known that these acids have an antimicrobial effect (Ohyama and McDonald, 1975) so the ammonia nitrogen relationship appears to be an indirect one.

Ohyama et al. (1980a) and Henderson et al. (1979) did not find silage water soluble carbohydrate (WSC) content of silages to be correlated with silage susceptibility to deterioration. Ohyama et al. (1980b) attempted to increase aerobic deterioration by the addition of glucose or starch and concluded that the occurrence of aerobic deterioration in good quality grass silages by growth of yeasts is likely to be affected by DM content rather than the existence of WSC. This is in agreement with earlier work (Ohyama et al. 1980a) showing that high DM silages seemed to be unstable.

Henderson et al. (1979) established no role of lactic acid or total acids on the deterioration of commercial silages. Ohyama et al. (1979) tested the theory that caproic acid would be effective in preventing aerobic deteroriation at a low silage pH; however, the addition of HCl to reduce the pH with caproic acid did not imorove the aerobic stability of Italian ryegrass silage.

Several silage additives affect the aerobic stability of silage and these may have varied effects depending on length of storage, rate of application, and residual levels of

the additive (Di Menna et al., 1981).

Theune and Honig (1980) used grass silages and suggested that high formaldehyde levels (1.35% of the DM) brought about chemical preservation; although, permanent stabilization was not reached because formaldehyde decomposed continuously. Final formaldehyde concentrations of .34 or .40% of the DM did produce stable silages. De Menna et al. (1981) added formalin or a combination of formalin-formic acid to grass and produced silages with a higher pH than untreated silages; even so, the treated silages were not less stable on exposure to air. Formic acid is strongly antibacterial and Crawshaw et al. (1980) showed a close association between bacterial numbers and aerobic activity of perennial ryegrass silages. These same workers showed propionic acid to be an effective treatment for inhibiting aerobic deterioration of silage which is consistant with its well known wide spectrum of antimicrobial properties.

Britt and Huber (1975) added NPN to corn silage in three forms (urea, aqua ammonia, and ammonia-molasses-mineral) and observed the aerobic stability of the silages. Days to maximum temperature were greater for the NPN treated silages although there were no differences in maximum temperature reached.

II. Microbiological Events Which Bring About Aerobic Deterioration.

Prior to the research of Beck and Gross (1964) it was known that micro-organisms were involved in the aerobic deterioration of silages, despite the fact that no detailed studies had been made to establish the particular organisms involved or the sequence of microbiological events. Beck and Gross (1964) established the significance of yeasts and

molds in the aerobic deterioration of some silages and suggested that silages with high populations of yeasts (> 10^5) were unstable after opening the silos. This data, suggesting yeast populations as the initial mechanism in aerobic deterioration, was not challenged until Woolford and Cook (1978) used antimicrobial techniques and suggested that in some silages aerobic deterioration was largely due to the activities of bacteria rather than yeasts and other types of fungi.

A clear definition of the microbial groups and the sequence of events involved in aerobic deterioration are still not known because of the many combinations of factors involved. Detailed studies have nearly always involved small quantities of silage and conditions abnormal from practical situations.

Moon and Ely (1979) recovered yeasts from wheat and alfalfa silages that could utilize lactic acid aerobically, but not anaerobically. Only one isolated yeast could utilize propionic acid aerobically and none of the yeasts utilized this acid anaerobically. However, all yeasts grew in complete media supplemented with propionic acid. Therefore, while lactic and propionic acids may contribute to stability under anaerobic conditions, they are probably less effective against yeast after the silage is exposed to air. Woolford et al. (1982) using whole crop barley silage with antimicrobical agents which were specifically inhibitory to mold or bacteria showed that aerobic deterioration of this crop was essentially caused by yeasts.

The research of Woolford and Cook (1978) showed bacteria to be involved in the initial stages of maize silage deterioration. These findings were followed by Barry et al. (1980) using several crops treated with formaldehyde-containing additives. They showed that when deterioration took place, both the initial heating and the rise in pH were related to counts of aerobic bacteria and that neither heating nor increasing pH were consistently related to yeast counts. It was suggested that acid-tolerant aerobic bacteria (perhaps assisted by yeasts in some cases) caused the first stage of aerobic deterioration

and that invasion by molds followed as a second stage of the deterioration process. The principle bacteria involved have been spore formers which are saccharolytic and proteolytic. Most bacteria have been identified as Bacillus spp. and some lactic acid bacteria.

Greater viable counts of aerobic bacteria and molds in initially exposed silages appeared to be correlated with lower DM, lower pH, and higher lactic acid contents in the silage; however, initial yeast counts were greater in silages of higher DM and lower organic acid contents (Ohyama et al., 1980a; Woolford, 1976).

In grass silages bacteria appear to be of little importance in the aerobic deterioration process (Woolford, 1978 and Ohyama et al., 1980a).

III. Characteristics Measured as Indicators of Aerobic Deterioration.

Dry matter loss, temperature rise, pH rise, oxygen consumption, and carbon dioxide production are the major characteristics used to describe the degree of aerobic deterioration taking place in silage. The aerobic deterioration ultimately results in the complete oxidation of a substrate to carbon dioxide and water. Oxygen consumption is a direct method of measuring the chemical processes and has been used by Pahlow (1980); although, the necessary equipment is expensive. The same chemical reactions can be monitored indirectly by measuring the carbon dioxide production (Honig and Woolford, 1980).

Honig and Woolford (1980) reported a linear association between temperature rise and carbon dioxide production in aerobically deteriorating silages. The temperature

measurements are easily affected by insulation and convection. Also, high moisture silages act as a heat sink and the DM loss per degree increase in temperature is dependent on the DM content of the silage.

The pH rise in aerobically deteriorating silage is caused by the use of lactic acid and volatile fatty acids as substrate by the microbial population (Moon and Ely, 1979; Moon et al., 1980).

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Materials and Methods

Harvesting and Ensiling Procedures: Four concrete stave silos (3.05 x 15.24 m) and one oxygen-limiting Harvestore® (7.0 x 9.15 m) were used to store approximately 25,450 kg per structure of high moisture corn (HMC) having 77.7 to 82.1% dry matter (DM). Corn was harvested September 11 to 13, 1979 and placed by silage blower into the storage structures. Stave silo HMC treatments were: 1) no additive (control), 2) 36.3 kg of sodium hydroxide (NaOH), 3) .91 kg of Silo-Best[1], and 4) 8.75 kg of Cold-flo[2] ammonia. High moisture corn ensiled in the Harvestore® and artificially dried corn (dry) were treatments 5 and 6, respectively. Additive rates were per 909 kg of wet corn which was harvested of the same field and variety. NaOH was added to the HMC as a dry ingredient and batch mixed in a Harsh mobile mixer wagon prior to the silo delivery. Silo-Best and Cold-flo ammonia were combined with the HMC at the silage blower. Silo-Best was added as a dry ingredient and ammonia was incorporated as an 85% liquid and 15% gas combination (approximate) by the use of the Cold-flo procedure developed by Pennsylvania State University in cooperation with USS Agri-Chemicals. Each load of corn was sampled for DM determination and composite samples were made for laboratory analyses. NaOH and Harvestore HMC were ensiled whole; the corn for the remaining treatments was coarsely cracked by a roller mill before ensiling. Harvestore and dry corns were coarsely rolled before feeding; NaOH corn was fed whole.

Cattle Feeding Trial: Silos were opened after 210 d and a complete mixed diet of each corn was full-fed twice daily for 93 d (April 9 to July 11, 1980) to 78 cattle (five

[1]Silo-Best® is a product of Cadco, Inc., Des Moines, Iowa. It contained dried fermentation products from A. oryzae, B. subtilis, and L. acidophilus.
[2]Cold-flo® is a non-protein nitrogen product of USS Agri-Chemicals, Division of United States Steel, P.O. Box 1685, Atlanta, Georgia.

individually fed steers/diet and two pens of four heifers/diet). The diets contained 83.2% corn, 4.5% forage sorghum silage, 4.5% alfalfa hay, and 7.8% supplement (DM basis) (table 1). All diets were theoretically formulated to 12% crude protein (CP), .80% calcium, and .32% phosphorous. Cattle were implanted with 36 mg of Ralgro[3], wormed with an oral paste at the start of the trial, and adjusted to full feed over 24 days. At the start and again at the end of the feeding trial, all cattle were weighed individually after 16 h without feed or water. Intermediate full weights were taken before the a.m. feeding on d 28, 56, and 84. Steer performance was based on beginning and ending live weights. Heifer final weights were derived from hot carcass weights and a dressing percentage of 62.

Ingredient samples were collected weekly and feed consumed was recorded daily. The quantity of complete diet offered was adjusted according to the amount the cattle would consume and feed was continually present in the feed bunks. Feed not consumed was removed, weighed, and discarded as necessary.

Rumen Fermentation Trial: Eighteen individually fed steers were fed the morning diet on May 10 and, subsequently, at 1, 3 and 5 h postfeeding, samples of rumen fluid were collected by stomach tube. Each sample was monitored for pH. Additionally, each sample had 18 ml of strained rumen fluid transferred to a 20 ml glass vial to which 2 ml of a 6 N HCl solution had been added. An aliquot was placed in a 1 ml serum vial for volatile fatty acids (VFA), lactic acid, and ammonia nitrogen analyses. These procedures were repeated on June 7 and July 5.

Lamb Digestion Trial: Three wether lambs were assigned to each of the six corn treatments for a replicated total collection digestion trial. Each wether received a diet which contained 77.2% of a respective corn, 19.0% alfalfa and 3.8% supplement (DM basis). Supplement formulation for the six diets is shown in table 2. Diets were fed twice daily for

[3]Ralgro® is a zeranol implant produced by International Minerals and Chemical Corp., Terre Haute, Indiana 47808.

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

THIS IS AS RECEIVED FROM CUSTOMER.

TABLE 1. COMPOSITION OF THE SUPPLEMENTS FED IN THE CATTLE FEEDING TRIAL

Ingredient[a]	Corn treatment		
	Dry, control Harvestore Silo-Best	NaOH	Ammonia
Corn, rolled	---	---	521.0
Soybean meal, 44% CP	450.0	450.0	---
Tallow	10.0	10.0	10.0
Urea, 281% CP	89.0	89.0	---
Limestone	260.0	260.0	260.0
Dicalcium phosphate	30.0	30.0	30.0
Salt	60.0	---	60.0
Potassium chloride	55.0	115.0	73.0
Ammonium sulfate	20.0	20.0	20.0
Vitamin A (10,000 IU/g)	8.9	8.9	8.9
Vitamin D (15,000 IU/g)	.6	.6	.6
Rumensin 60	2.5	2.5	2.5
Tylan 10	9.0	9.0	9.0
Trace mineral[b]	5.0	5.0	5.0

[a] kg/1000 kg.
[b] Z-10, a product of Calcium Carbonate Company.

TABLE 2. COMPOSITION OF THE SUPPLEMENTS FED IN THE LAMB DIGESTION TRIAL

Ingredient[a]	Corn treatment		
	Dry, control Harvestore Silo-Best	NaOH	Ammonia
Corn, rolled	---	11.5	521.0
Soybean meal, 44% CP	450.0	450.0	---
Tallow	10.0	10.0	10.0
Urea, 281% CP	89.0	89.0	---
Limestone	260.0	260.0	260.0
Dicalcium phosphate	30.0	30.0	30.0
Salt	71.5	---	71.5
Potassium chloride	55.0	115.0	73.0
Ammonium sulfate	20.0	20.0	20.0
Vitamin A (10,000 IU/g)	8.9	8.9	8.9
Vitamin D (15,000 IU/g)	.6	.6	.6
Trace mineral[b]	5.0	5.0	5.0

[a] kg/1000 kg.
[b] a product of Calcium Carbonate Company.

ad libitum consumption during a 15 d period; subsequent intake was reduced to 90% for a 7 d total collection of feces and urine. Lambs were fitted with a canvas harness equipped with a fecal collection bag and fed in individual metal digestion crates. The ambient temperature was 21 C. Daily fecal collections were weighed and a 10% sample was retained and its DM determined daily and a composite of the daily samples was analyzed for total nitrogen and ash.

Crates were equipped with stainless steel trays below the wire-mesh floor to direct urine into a plastic bucket containing 50 ml of 18 N HCl to inhibit bacterial action and to fix free ammonia in the urine. Urine collections were diluted with water to the next highest liter and a 10% aliquot was taken and stored in glass bottles. The composite urine sample was analyzed for total nitrogen.

Diet ingredients were sampled daily and each was composited for the 7 d collection period for DM determination and laboratory analyses. Feed refusals, when present, were collected and sampled daily for DM and laboratory analyses.

Aerobic Stability Trial: Aerobic stability (bunk life) of each corn treatment was measured using samples taken on May 13 (replication 1) and July 1 (replication 2). A 36 kg batch of ensiled HMC was removed at a 1 m depth below the surface in each silo (Harvestore and dry corn batches were taken following daily corn removal). The batchs were individually mixed and sampled and each batch was divided into 12 lots containing 2.5 kg of corn. Each of the 12 lots was placed in an expanded polystyrene container having a plastic bag liner. A thermocouple was placed in the center of each container and cheese cloth stretched across the top. Containers were stored at approximately 21 C and temperature within each container was monitored. Following air exposures of 48, 112, 160, and 340 h or 86, 163, 208, and 349 h for the replications 1 and 2, respectively; triplicate containers of each corn treatment were weighed, mixed, and sampled. Dry matter content and DM losses were determined and samples were analyzed for pH, total nitrogen, ammonia

nitrogen, VFA, lactic acid, and microflora.

Bacteria and mold colony counts were determined by aseptically placing 11 g of corn into 99 ml of a sterile phosphate buffered distilled water solution and homogenizing the mixture in a sterile glass Waring blender for 2 min. From this primary dilution (1:10) a series of dilutions were made for plate cultures and the plates were incubated for 3 d at 28 C. Standard plate counts were made from two duplicate plates with appropriate dilutions. Plate count agar (PCA, Difco; with 100 ug/ml cycloheximide added) was used for total aerobic bacterial counts. For mold counts, potato dextrose agar (PDA, Difco; with 100 ug/mg of chloramphenical and chlortetracycline) were used.

Particle Size Determination: Particle size determinations were made using three replicate composite samples of each corn treatment. A 100 g dried sample was sifted over 15 sieves having the following micron diameter openings: 7925, 5613, 3360, 2380, 1680, 1190, 841, 595, 420, 297, 210, 149, 105, 74, 53 and pan. The method of determining and expressing fineness of feed materials by sieving are described in detail by Pfost et al. (1976).

Laboratory Analyses: Wet sample collections were stored at -10 C until analyzed. Sample DM was determined by drying for 48 h at 55 C in a forced-draft oven with no corrections for volatile losses. The dried corn and supplement samples were subsequently ground in a food processor (La Machine®, Model 354, Moulinex Products Inc., 2820 Crusader Circle, Virginia Beach, Virginia) and dried forage and feces were ground with a Wiley mill to pass through a 1 mm screen. Proximate analysis was determined by AOAC (1970).

For wet analysis the portion of sample not dried had a 25 g aliquot extracted in 100 ml of distilled water for 1 h and pH determined. Another 25 g aliquot was extracted in 200 ml of .2N H_2SO_4 for 2 d and the supernate was strained through 4 layers of cheesecloth from the mixture and retained for further analysis. From the supernate, lactic acid was

determined by colorimetric determination (Barker and Summerson, 1941); ammonia-nitrogen by the Conway microdiffusion method (Conway, 1957); and VFA by gas chromatography. VFA were separated using a Hewlett-Packard gas chromatograph with a 182.9 cm glass column having an ID of 4 mm; column packing was 100 to 120 mesh Chromosorb 101.

Statistical Analyses: Statistical analyses of experimental data were performed using the Statistical Analysis Systems (Barr et al., 1979). One-way analysis of variance procedures (Snedecor and Cochran, 1980) were used to measure variations among particle size determinations and heifer performance data with Proc Anova; Duncan's Multiple Range (Duncan, 1955) test was used to compare treatment means.

The general linear model procedure (Proc GLM) was used to measure variation in steer performance data, rumen fluid data, and lamb digestion data; means were compared by the method of Least Significant Difference (LSD) protected by a significant F value (Steel and Torrie, 1960).

The rumen fluid data were analyzed with a split-split plot model. The whole plot experimental unit was an animal; the sub-plot experimental unit was the d of sampling and the sub-sub plot experimental unit was the h of sampling. In each statistical analysis a minimum significance level of 5% was used to determine differences.

Results and Discussion

Chemical Analyses of the Six Corn Treatments: Weekly corn samples during the Cattle Feeding Trial were composited by equal weight within treatments for laboratory analyses. These samples were representative of the corn being fed to the cattle and were affected by aerobic deterioration. This deterioration was enhanced by the warm ambient temperatures and the ensiled HMC surface areas in the staves being exposed to air for 3 to 8 d due to slow feeding rates. The Harvestore structure was filled to 20% capacity initially and aerobic conditions persisted during feedout, when unloading augers were not always maintained in an air-tight manner.

The fermentation acids produced during the ensiling process are shown in table 3. Ammonia treated HMC had the highest lactic acid value (.75% of the DM); Harvestore and control HMC had the next highest values (.58% and .43%, respectively). NaOH treated HMC had .38% of the DM as acetic acid, which was the the highest value among treatments, and was twice the value of Silo-Best treated HMC, which had the next highest value. The remaining VFA concentrations (propionic, butyric, isobutyric, valeric, and isovaleric) individually represented less than one-tenth of one percent of the DM for all corn treatments. The sum of lactic and acetic acid values, as a percent of the DM, for the corn treatments gave the following ranking from highest to lowest: ammonia, .87; Harvestore, .70; NaOH, .64; control, .53; Silo-Best, .49; and dry, .21.

Otterby *et al.* (1976) and Huber *et al.* (1973) using ammonia additions to HMC and corn silage, respectively, have shown decreased lactic acid concentrations following fermentation. Results of Thornton et al. (1977) using HMC in experimental silos showed that treatment with .1% to .4% ammonia increased fermentation, as measured by lactic acid content; whereas, treatment with .6% ammonia or higher retarded fermentation, as

TABLE 3. CHEMICAL ANALYSES OF THE SIX CORN TREATMENTS[a]

Item	Dry	Control	Harvestore	Silo-Best	Ammonia	NaOH
Dry matter, %	89.6	82.0	77.7	81.4	79.0	82.1
pH	5.5	6.4	7.6	6.4	7.8	8.8
			% of total N			
Ammonia nitrogen	.47	5.14	11.96	4.19	18.66	1.81
Acid-detergent nitrogen	3.03	7.67	3.25	4.78	5.78	12.75
			% of DM			
Crude protein	9.49	8.96	9.04	9.15	9.95	8.68
Lactic acid	.194	.433	.579	.350	.754	.264
Acetic acid	.014	.096	.121	.140	.117	.379
Valeric acid	.030	.021	.015	.015	.027	.087
Total acids	.238	.550	.715	.505	.898	.720

[a] Nine weekly samples were composited, sampled, and analyzed.

indicated by very low levels of lactic acid and elevated pH. When ammonia losses during application (which are described later) are considered, the increased fermentation acids for the ammonia treatment agree with the data of Thornton et al. (1977).

Values for pH of the weekly corn samples were unexpectedly high for the Harvestore, control, and Silo-Best corns. These high pH's reflect the aerobic deterioration which was occurring at the surface of the ensiled HMC as they were being fed (Moon and Ely, 1979; Moon et al., 1980). Ammonia and NaOH treated HMC had the highest pH values, which reflect the basic pH of the additives applied.

Ammonia nitrogen, expressed as a percent of the total nitrogen, was 18.7% for ammonia treated HMC and 12.0% for Harvestore HMC; values for remaining corn treatments were less than 5.2%. Proteolysis and formation of ammonia nitrogen during storage and feedout of the Harvestore corn may also have contributed to its high pH value (Woolford, 1978). Catabolized amino acids and the ammonia liberated by deamination have been shown to increase pH in fermented feeds (McDonald, 1981).

The ammonia treated HMC was 9.36% CP before treatment and 9.95% CP when fed. The 8.75 kg of Cold-flo ammonia added per 909 kg should have raised the CP to 14.3%; thus, only 12% of the Cold-flo nitrogen added was retained with the treated corn at the time of feeding. Ammonia losses at the silage blower and during silo filling were enhanced by the high DM of the ensiled corn. Other losses reported for ammonia application to HMC using aqua solutions were 19% (Lancaster et al., 1974), 55% (Britt and Huber, 1976), and 78% (Peplinski et al., 1978). Saenger et al. (1982) added ammonia to 72% DM HMC at the silage blower, similarly to the trial reported here, and found that no ammonia was retained in the ensiled HMC.

The CP value for the dry corn was one half of one percent higher (9.49 vs approximately 9.00) than all HMC, except for the NaOH corn, which had a CP value of 8.61%. The volatilization of ammonia occurs with increasing pH (McDonald, 1981) and this

may explain the greater loss of nitrogen in the NaOH HMC compared with Silo-Best and control HMC.

The highest acid-detergent nitrogen value was for the NaOH treated HMC. This was, likely, a result of the extensive heating that occurred during the time of NaOH application and the heat retained within the corn mass from the heat of chemical reaction of NaOH with the corn moisture inside the silo.

Surface discoloration of the corn kernels was evident within 3 to 5 min after NaOH application. The kernels turned from a bright yellow to a dark yellow color with shades of dark tan to brown. After NaOH treatment, the surface of the corn kernels became slimy and adherent and this reduced the physical flow characteristics of the corn. These handling problems decreased the silage blower capacity and created several shut-downs during silo filling due to a choked silage blower or blower pipe. Kernels of the NaOH treated HMC were a dark brown to a black color when fed. Due to extremely hard compaction, an axe was required to dislodge sufficient corn for daily feeding, but the integrity of the whole kernel was generally maintained. Bettenay (1980) stated that barley, when treated with 35 g NaOH/kg of air dry grain, needed to be physically moved a few h after NaOH application to prevent compaction. The discoloration of the grain following NaOH treatment observed in the trial reported here has not been mentioned in previous research reports.

Ammonia treated HMC was discolored due to the reaction between corn lipids and ammonia. These kernel parts were a light to dark tan color compared with a bright yellow color for the surface of the Silo-Best and control HMC kernel fragments. The extent of this reaction is dependent on conditions such as, level of added ammonia, corn DM content, reaction temperature, and reaction time (Brekke et al., 1977). The ammoniated pigments are largely water soluble because the original color returns upon soaking the corn in water. A more intensive study of ammonia and corn reactions was made by Black et al. (1978) with the discovery that corn lipids, particularly 18:2 and 18:3, in the presence of oxygen form a

nitrogenous derivative that is unextractable with the usual fat solvents.

Moisture migration was evident within the HMC in all stave silos, with more free moisture present along the concrete walls. This was a practical consequence of the warm corn mass having contact with the concrete staves, which were cooler and condensed moisture on the silo interiors. Small confined amounts of visual microbial growth occurred in the NaOH treated HMC; the ensiled surface along the circumference of the silo contained a higher percent moisture and was susceptible to limited microbial growth. However, in general, the NaOH treated HMC was stable when it was exposed to air during feedout.

Silo-Best, ammonia, control, and Harvestore HMC all showed evidence of aerobic deterioration during the Cattle Feeding Trial. Harvestore corn kernels were a light to dark grey; this discoloration was usually present on only a portion of the kernel and appeared to be microbial growth. In addition, the Harvestore corn had a slight musty odor when unloaded for feeding. Silo-Best, ammonia, and control HMC all showed visual microbial growth on the ensiled surfaces exposed to air. Deterioration was particularly prevalent along the inside wall of the silos, where levels of moisture were elevated due to condensation following moisture migration. Surface removal rate was less than 8 cm/d, which contributed to the aerobic deterioration. A ranking of the degree of deterioration among the HMC treatments was difficult from these observations alone; therefore, a more detailed Aerobic Stability Trial, was conducted.

Cattle Feeding Trial: Performances of the steers and heifers are shown in tables 4 and 5. Dry matter intake (DMI) for individually fed steers were similar among corn treatments (table 5), but rate of gain for steers fed NaOH treated corn was less ($P<.05$) than gains for steers fed all other corns, except those fed ammonia treated corn. NaOH treated corn was used the least efficiently ($P<.05$) by the steers. For group fed heifers (table 5), DMI was higher ($P<.05$) for Silo-Best and NaOH treated HMC than for Harvestore

TABLE 4. PERFORMANCE OF STEERS FED THE SIX CORN DIETS

Item	Dry	Control	Harvestore[1]	Silo-Best	Ammonia	NaOH
Number of steers	5	5	4	5	5	5
Initial weight, kg	291	294	286	296	297	290
Final weight, kg	422	427	415	434	415	390
Average daily gain, kg	1.44 [a]	1.47 [a]	1.42 [a]	1 .52 [a]	1.30 [ab]	1.10 [b]
Daily feed intake, kg[2]	8.20	8.36	7.74	8.57	7.71	8.60
Feed/gain[b]	5.72 [a]	5.78 [a]	5.50 [a]	5.62 [a]	6.08 [a]	8.07 [b]

[1] One steer died.
[2] 100% dry matter basis.
[a,b] Values with unlike superscipts differ significantly (P<.05).

TABLE 5. PERFORMANCE OF HEIFERS FED THE SIX CORN DIETS

Item	Dry	Control	Harvestore	Silo-Best	Ammonia	NaOH
Number of heifers	8	8	8	8	8	8
Initial weight, kg	250	249	253	253	252	251
Final weight, kg	370	365	373	375	363	366
Average daily gain, kg	1.32	1.28	1.33	1.34	1.23	1.27
Daily feed intake, kg[1]	7.80 [ab]	8.02 [ab]	7.48 [b]	8.25 [a]	7.84 [ab]	8.51 [a]
Feed/gain[1]	5.93 [ab]	6.29 [abc]	5.66 [a]	6.16 [abc]	6.40 [bc]	6.72 [c]

[1] 100% dry matter basis.
[a,b,c] Values with unlike superscipts differ significantly (P<.05).

HMC. Rates of gain were all statistically similar among heifers receiving the six corn diets, but gains were numerically lowest for heifers fed the control, ammonia, and NaOH corns. Harvestore corn resulted in the lowest ($P<.05$) feed/gain; while NaOH corn resulted in the highest ($P<.05$) feed/gain.

The actual CP of the diets for the ammonia and NaOH corns were 10.5 and 11%, respectively; whereas, CP of the other diets was 12%. Preston (1982) suggested that the initial CP of the diet (first 28-56 d) should be near 12% and that CP intake should not decrease below .87 kg head^{-1} d^{-1}. Heifers and steers receiving the ammonia diet would have received less than the .87 kg of CP head^{-1} d^{-1} for the duration of the trial and this may explain their poor performance.

For both steers and heifers, NaOH addition increased feed intakes but feed conversions were not improved. The high sodium content of NaOH diet increased water intake and subsequent urine excretion, which was verified by observations of the excreta in pens. The reduced rumen retention time associated with NaOH additions (Berger et al., 1980; Berger et al., 1981; Horn et al., 1981) may also explain the reduced cattle performance from the NaOH diet.

Although the control, Silo-Best, and Harvestore HMC were unstable on exposure to air; cattle performances from these diets were similar to the dry corn diet. Guyer and Farlin (1976) reported better gain and feed conversion from Harvestore HMC than from dry corn or HMC ensiled in a bunker. However, Merrill (1971) in a reveiw concluded that differences in feeding value among oxygen-limiting structure, conventional silo, or bunker stored HMC were minimal and differences were due more to feeding management than storage structure.

Rumen Fermentation Trial: Table 6 presents means for rumen pH, molar proportions of VFA, lactic acid, and ammonia concentrations by corn treatment averaged over observation h (1, 3, and 5 postfeeding) and observation d (May 10, June 7, and July 5). Analysis of

TABLE 6. RUMEN FERMENTATION ANALYSES FOR STEERS FED THE SIX CORN DIETS, AVERAGED OVER SAMPLING HOURS AND OBSERVATION DAYS[a]

Item	Dry	Control	Harvestore	Silo-Best	Ammonia	NaOH
pH	6.3	6.3	6.1	6.1	6.3	6.1
	molar %					
Propionic	47.0	41.5	49.0	46.7	45.8	39.1
Acetic	44.4	46.8	43.1	44.6	45.3	48.5
A/P	1.0	1.3	.9	1.0	1.0	1.3
Isobutyric	1.0	.9	.6	.7	.8	.8
Butyric	5.5	8.4	5.6	6.3	6.5	9.8
Isovaleric	1.0	1.5	.5	.9	.7	.9
Valeric	1.1	.9	1.2	.8	.9	1.1
	mg/dl					
Lactic	23.5	24.2	25.7	25.8	27.5	30.2
Ammonia	7.9	8.2	10.3	9.3	6.0	9.7

[a] Each value represents the mean of 27 observations.

variance tables are presented in appendix tables 1-10 and show the sources of variation and levels of significance for the rumen fermentation analyses.

No significant differences ($P<.05$) in rumen pH were attributed to the corn diets (table 6). There were significant differences ($P<.0001$) among d and also within h ($P<.0001$) for rumen pH (appendix table 1). Rumen pH (appendix table 11) was higher at h 5 (6.3) than at h 1 and 3 (6.1 and 6.1; respectively) and rumen pH on June 7 (6.0) was lower than either May 10 or July 5 (6.2 and 6.4; respectively).

There were no significant differences ($P<.05$) among corn treatments for the molar proportions of propionic, acetic, acetic/propionic, isobutyric, butyric, isovaleric, or valeric acids found in the rumen fluid (table 6). Some VFA did have d and/or h as significant ($P<.05$) terms (appendix tables 2 to 8), but only valeric acid had a significant ($P<.05$) d x h interaction (appendix table 12).

When corn treatments were compared over observation d, trends occurred in the VFA results. The Harvestore corn diet gave the highest molar proportion of propionic acid (appendix table 13); the NaOH corn diet gave the highest molar proportion of acetic acid (appendix table 14). The higher molar proportion of acetic acid found in the rumen fluid of steers fed the NaOH diet is in agreement with several other reports (Thomson et al., 1978; Rogers et al., 1979; Orskov and Reid, 1979; Sirskandarajah et al., 1980). This also agrees with results of Rogers and Davis (1980) who constantly infused mineral salts of $NaHCO_3$ or NaCl into the rumen of fistulated steers. They observed that as the total fluid outflow from the rumen increased; the total VFA concentration decreased, molar percent acetic acid increased, and molar percent propionic acid decreased.

The acetic/propionic ratios were highest for control and NaOH corn diets (1.3 and 1.3, respectively) and similar (approximately 1.0) for the other four corn diets (table 6). A small acetic/propionic ratio for the Harvestore corn diet and a larger ratio for the NaOH corn diet may explain the improved cattle performance from Harvestore corn over the NaOH

corn (Wolin, 1960; Hungate, 1966; Richardson et al., 1976); however, such interpretations need to be made with caution (Sharp et al., 1982; Van Soest, 1982).

There was a significant (P<.0028) increase in the acetic/propionic ratios over the three observation d, with mean ratios for May 10, June 7, and July 5 being .9, 1.1, and 1.3; respectively (appendix table 15). The molar proportion of butyric acid means over sampling h (appendix table 16) and observation d (appendix table 17) both tended to be highest for the control and NaOH corn diets.

Lactic acid means over all sampling h and d were lowest for the dry corn diet and highest for the NaOH corn diet (table 6). There were no apparent trends over the three observation d for any of the corn diets to give the highest or lowest lactic acid value in the rumen.

Ammonia concentrations in the rumen averaged over sampling h and observation d were highest for the Harvestore corn diet and lowest for the ammonia corn diet (table 6). The ammonia corn diet gave the lowest rumen ammonia values on each of the three observation d (appendix table 18), which was likely the result of a lower total nitrogen content in this diet compared with the other five corn diets. Rumen ammonia concentrations increased over observation d (P<.0004) and decreased (P<.0001) over sampling h (appendix table 19).

Lamb Digestion Trial: Means over periods for daily intake, apparent digestion coefficients, and nitrogen balance are shown in table 7. The diet ingredient chemical compositions are shown in tables 8 and 9 for periods 1 and 2, respectively. Data for each lamb by periods are presented in appendix tables 20 to 25 and the analysis of variance tables are presented in appendix tables 26 to 32.

No significant differences (P<.05) were found for apparent digestibilities of DM or organic matter among the six corn diets. Crude protein digestibility was less (P<.02) for the NaOH diet compared with all other diets. The high acid-detergent nitrogen content for the

TABLE 7. DAILY INTAKE, APPARENT DIGESTIBILITY, AND NITROGEN BALANCE FOR LAMBS FED THE SIX CORN DIETS

Item	Dry	Control	Harvestore	Silo-Best	Ammonia	NaOH
Number of lambs	6	4	6	5	6	6
Dry matter intake, g/d	1056.9	1198.3	1173.3	1197.0	1168.3	1234.4
	% Apparent digestibility					
Dry matter	80.7	82.5	78.8	82.9	81.1	78.1
Organic matter	82.0	83.6	79.9	84.1	82.3	78.6
Ash	57.0	60.5	57.5	57.0	57.5	69.6
Crude protein	72.7 [a]	70.8 [a]	66.7 [a]	78.6 [a]	67.9 [a]	50.7 [b]
	Nitrogen balance					
N intake, g/d	22.2	22.8	23.6	23.7	21.8	22.6
N retained, g/d	4.7	6.8	6.4	8.4	6.0	5.5
N retained, as % of N intake	21.3	29.3	27.1	35.8	27.8	24.4
N retained, as % of absorbed N	26.1	40.9	39.5	51.1	39.3	49.0

[1] Least-squares means.
[a,b] Values with unlike superscripts differ significantly ($P<.05$).

TABLE 8. DIET INGREDIENT CHEMICAL COMPOSITION IN THE LAMB DIGESTION TRIAL; PERIOD 1 (MAY 16-MAY 22)

Item	Organic matter	Crude protein	Ash
Corn:		%, DM basis	
Dry	98.11	10.55	1.89
Control	98.79	8.98	1.21
Harvestore	98.65	9.71	1.35
Silo-Best	98.57	9.74	1.43
Ammonia	98.52	10.52	1.48
NaOH	94.88	9.46	5.12
Alfalfa hay	90.34	17.26	9.66
Supplement: ammonia corn	55.57	13.22	44.43
Supplement: NaOH corn	57.01	37.29	42.99
Supplement: Harvestore, dry, Silo-Best, control corns	49.68	43.31	50.32

TABLE 9. DIET INGREDIENT CHEMICAL COMPOSITION IN THE LAMB DIGESTION TRIAL; PERIOD 2 (JULY 15-JULY 21)

Item	Organic matter	Crude protein	Ash
Corn:		%, DM basis	
Dry	98.59	10.09	1.41
Control	98.53	10.03	1.47
Harvestore	98.38	9.93	1.62
Silo-Best	98.37	9.44	1.63
Ammonia	98.32	10.40	1.68
NaOH	95.26	8.65	4.74
Alfalfa hay	90.24	17.07	9.76
Supplement: ammonia corn	54.81	10.24	45.19
Supplement: NaOH corn	57.68	40.65	42.32
Supplement: Harvestore, dry, Silo-Best, control corns	52.41	49.77	47.59

NaOH treated HMC (table 3) may partially explain this reduced protein digestibility. Acid-detergent nitrogen is an indigestible nitrogen fraction (Van Soest, 1967). Apparent organic matter digestibility was the lowest, although not significant, for the NaOH diet, which agrees with the results of the Cattle Feeding Trial. However, the low apparent organic matter digestion coefficient for Harvestore HMC is not in agreement with the Cattle Feeding Trial and the reason for the discrepancy is not evident.

One lamb receiving the dry corn diet during period 1 had a negative nitrogen retention; all other lambs had positive nitrogen retention. There were no significant differences ($P<.05$) among corn treatments in the g of nitrogen retained/d, nitrogen retained as a percent of nitrogen intake, or nitrogen retained as a percent of the absorbed nitrogen.

Usually digestion trials give little information concerning the extent to which ash is actually digested and absorbed, since calcium, phosphorous, iron, and magnesium are largely excreted from the body in the feces (Schneider and Flatt, 1975). The digestibility of ash is not determined because much of the fecal ash is not undigested dietary ash. However, apparent ash digestibilities were included in table 7 and these show that a large portion of the sodium was most likely absorbed from the gut and excreted in the urine. This resulted in a relatively high apparent ash digestibility for the NaOH corn diet.

Aerobic Stability Trial: Mean daily temperature of the corn treatments and their accumulated temperature above ambient for replications 1 and 2 of the Aerobic Stability Trial are presented in figures 1 to 4.

The Harvestore and ammonia HMC in both replications were highly unstable when exposed to air. In replication 1, their mean temperature decreased initially as temperatures equilibrated to ambient but then increased sharply to first peaks at about 50 h (figure 1). These peaks were followed by decreasing temperatures until 110 to 120 h, when a second period of heat production occurred. A similar pattern of heat production was observed in

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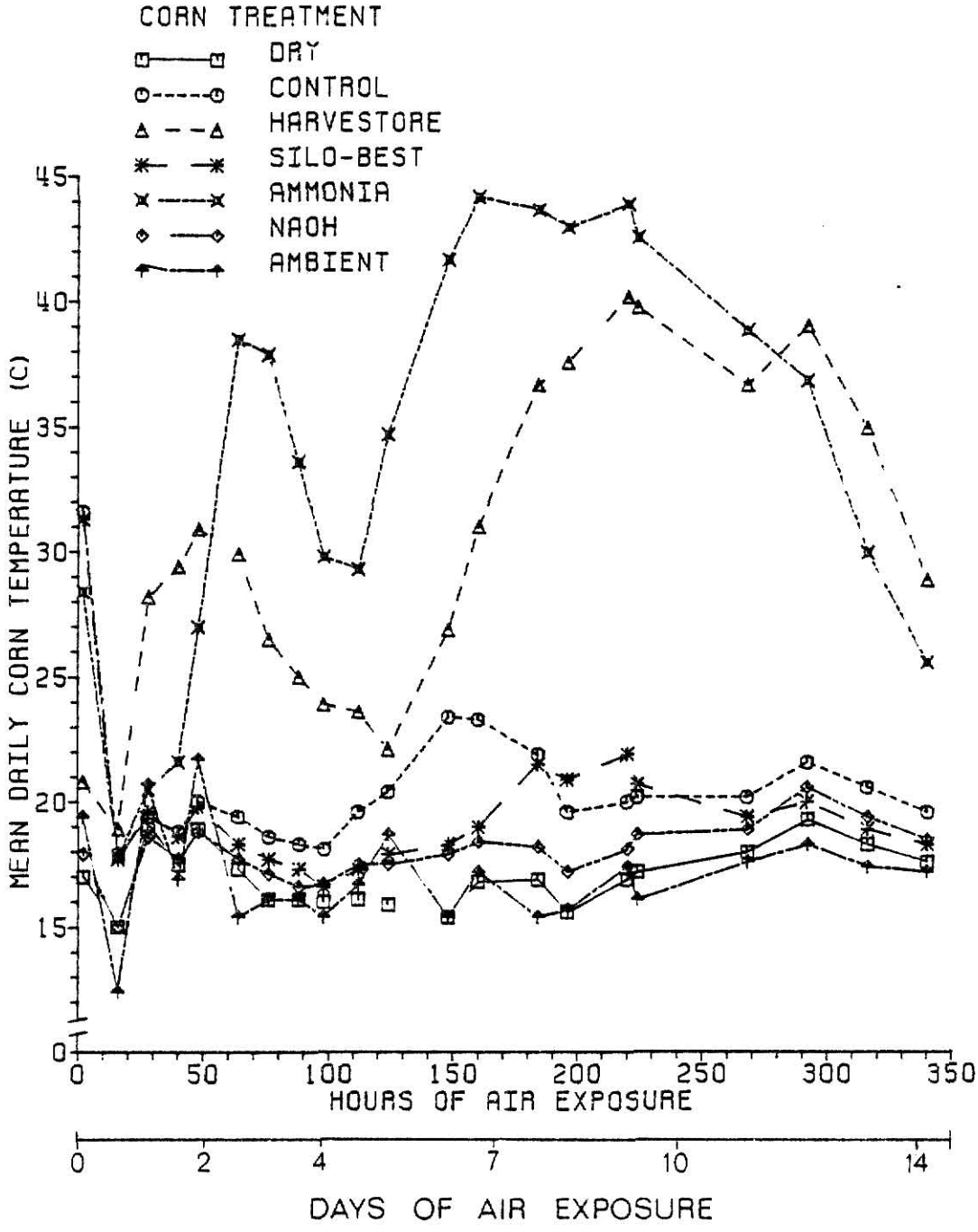

Figure 1. Replication 1: Mean daily corn temperature.

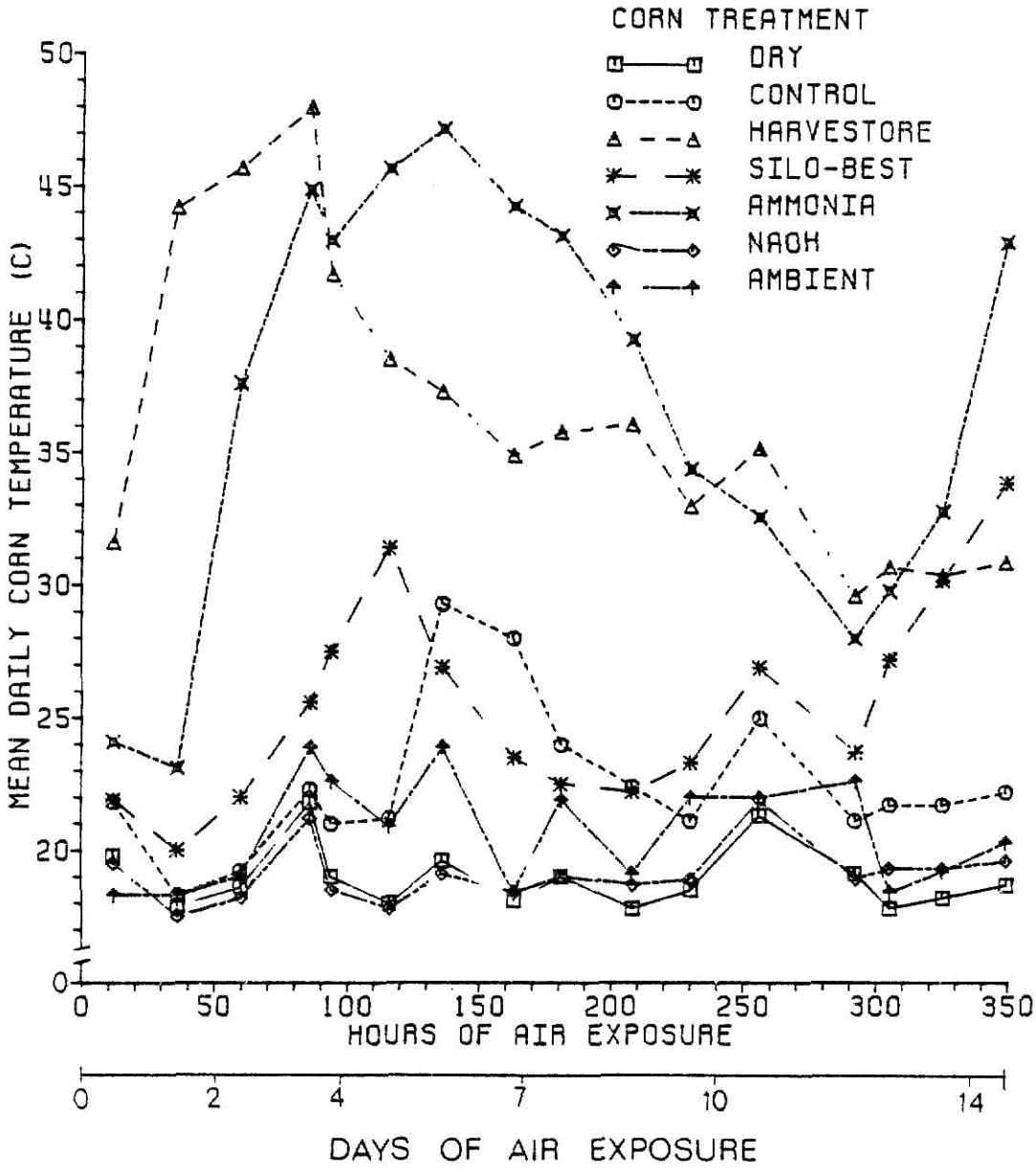

Figure 2. Replication 2: Mean daily corn temperature.

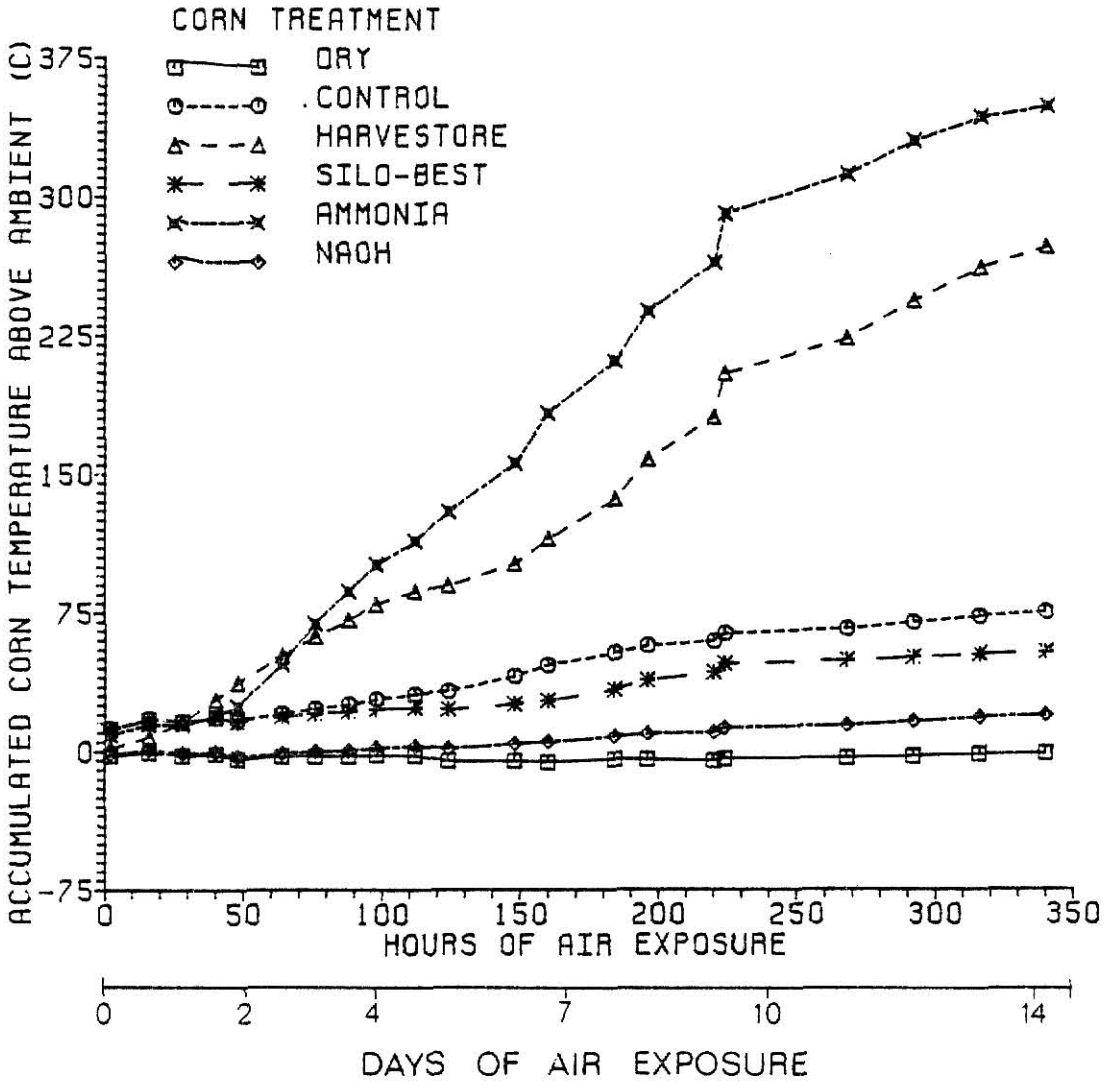

Figure 3. Replication 1: Accumulated corn temperature above ambient.

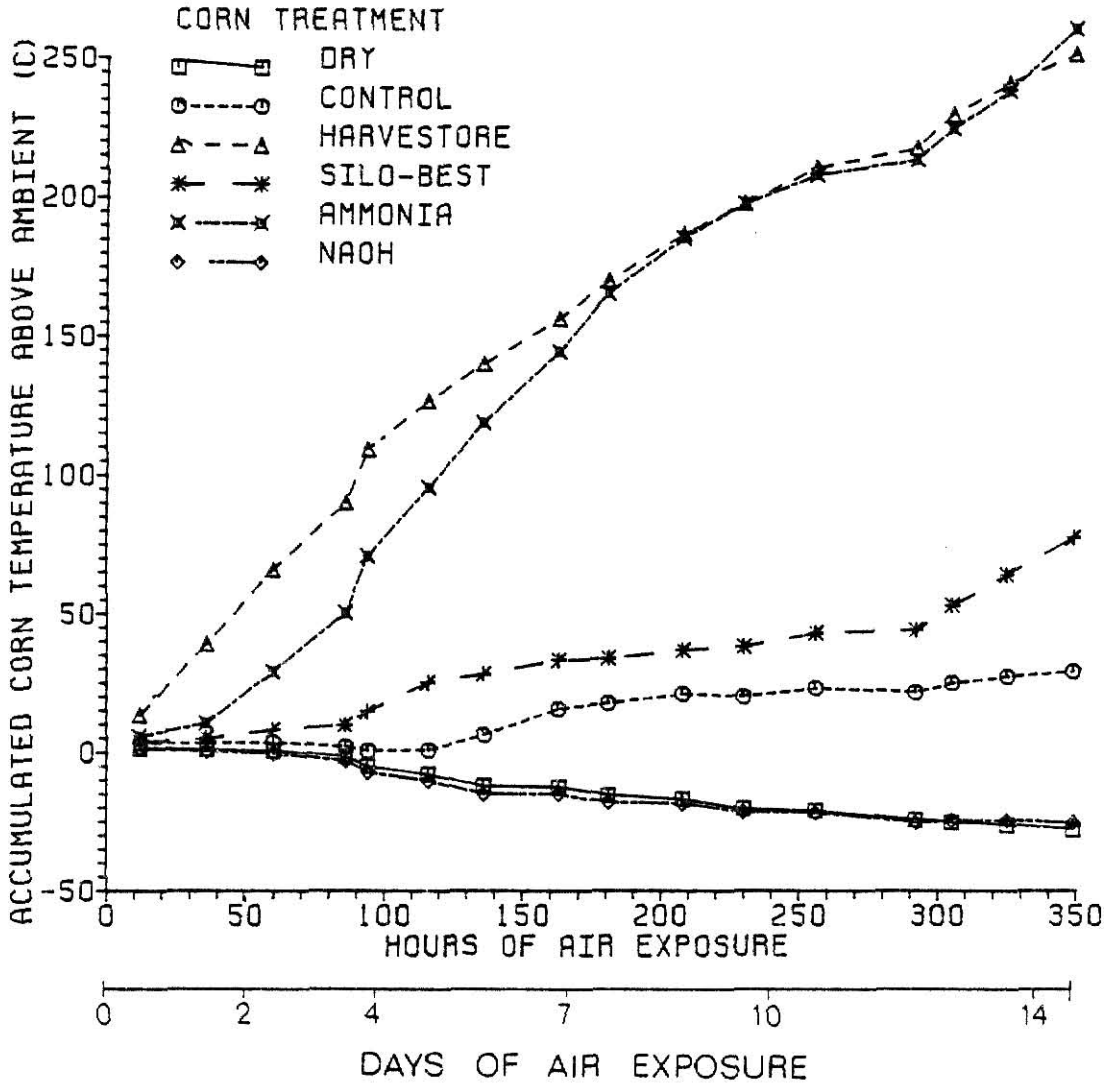

Figure 4. Replication 2: Accumulated corn temperature above ambient.

replication 2 (figure 2), except that the initial mean temperature rises were higher and of longer duration and a second temperature rise was delayed until 280 h for the ammonia treated corn. A second temperature rise did not occur in the Harvestore HMC during replication 2.

Accumulated corn temperatures above ambient (figures 3 and 4) clearly show that the Harvestore and ammonia HMC were the least aerobically stable corn treatments. Harlan (1977) reported HMC treated with ammonia to be aerobically less stable with higher temperature increases than control HMC. Accumulated temperatures for control and Silo-Best HMC were consistently higher than those of the dry or NaOH corns. Silo-Best HMC did have a rapid temperature rise during the latter h of replication 2. The NaOH HMC and dry corn were the most aerobically stable and had similar mean temperatures above ambient.

Bacteria and mold counts for replications 1 and 2 of the Aerobic Stability Trial are presented in figures 5 to 8. Initial mold and bacteria counts were not determined for replication 2 and yeast counts were not made in either replication. Yeasts were shown to be the agent of initial aerobic deterioration in many whole-crop silages (Honig and Woolford, 1980; Woolford et al., 1982) and can grow at low pH (Ohyama et al., 1975). Ohyama et al. (1980) studied the deterioration of grass silages and suggested an initial competition between bacteria and yeasts and that yeasts played the predominant role in aerobic deterioration. However, Woolford and Cook (1978) found that bacteria did have a role in the deterioration of corn silage.

In general, dry, control, and Silo-Best corns had similar bacteria counts in both replications and Harvestore corn had high bacteria counts in both replications (figures 5 and 6). Ammonia corn had low bacteria counts during the first 50 h of replication 1, which was followed by a rapid and sustained increase in bacteria counts. Ammonia corn had high bacteria counts throughout replication 2. This agrees with the work of Dalmacio (1976)

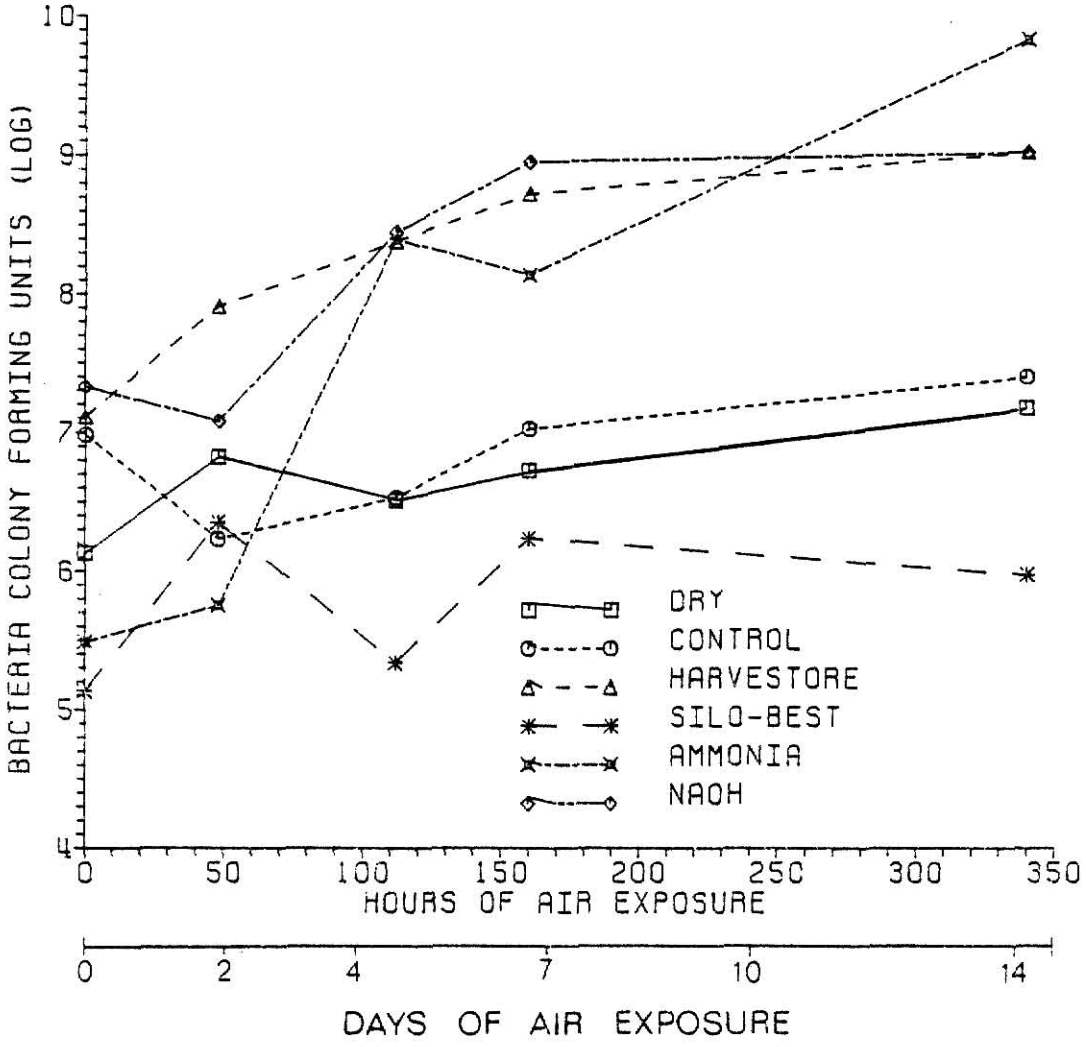

Figure 5. Replication 1: Bacteria colony forming units.

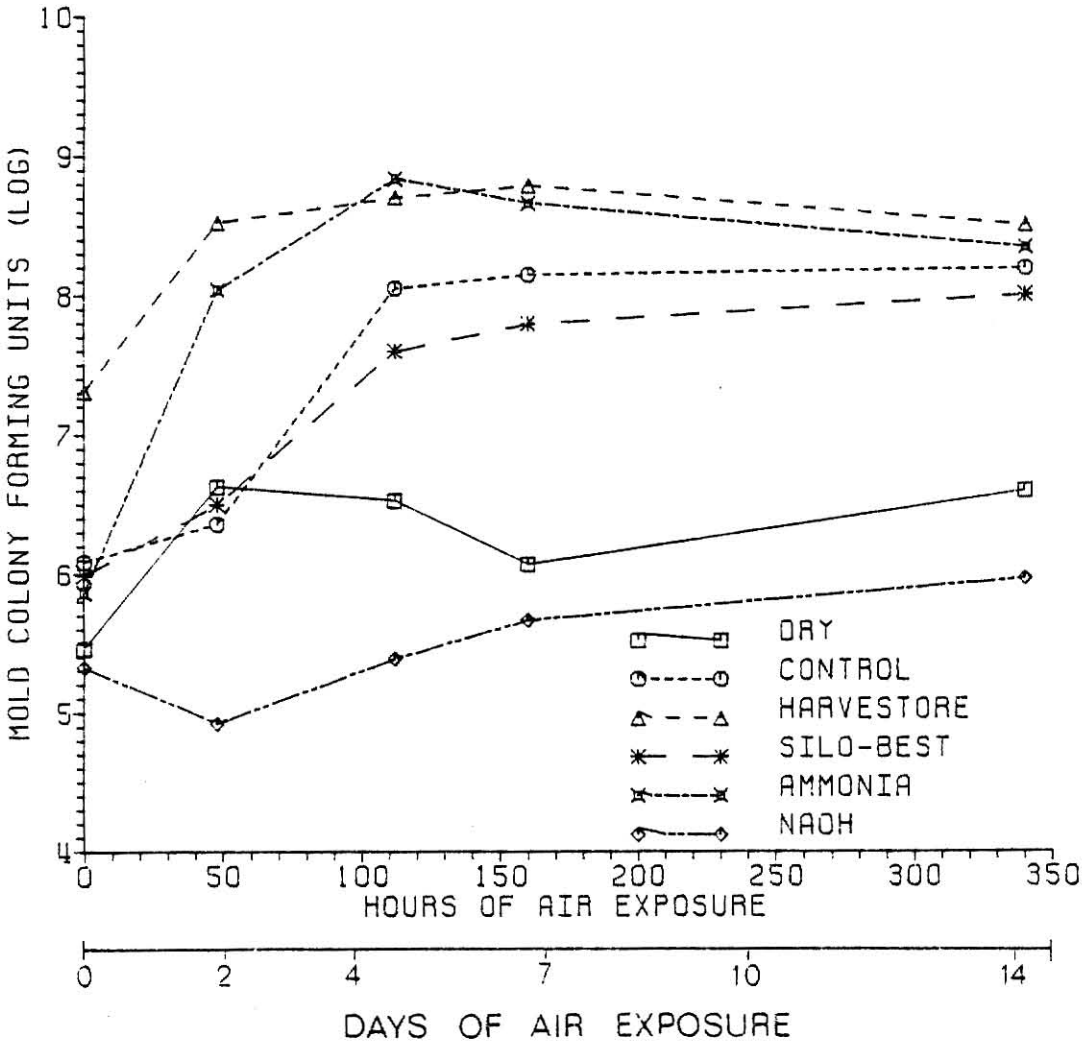

Figure 6. Replication 2: Bacteria colony forming units.

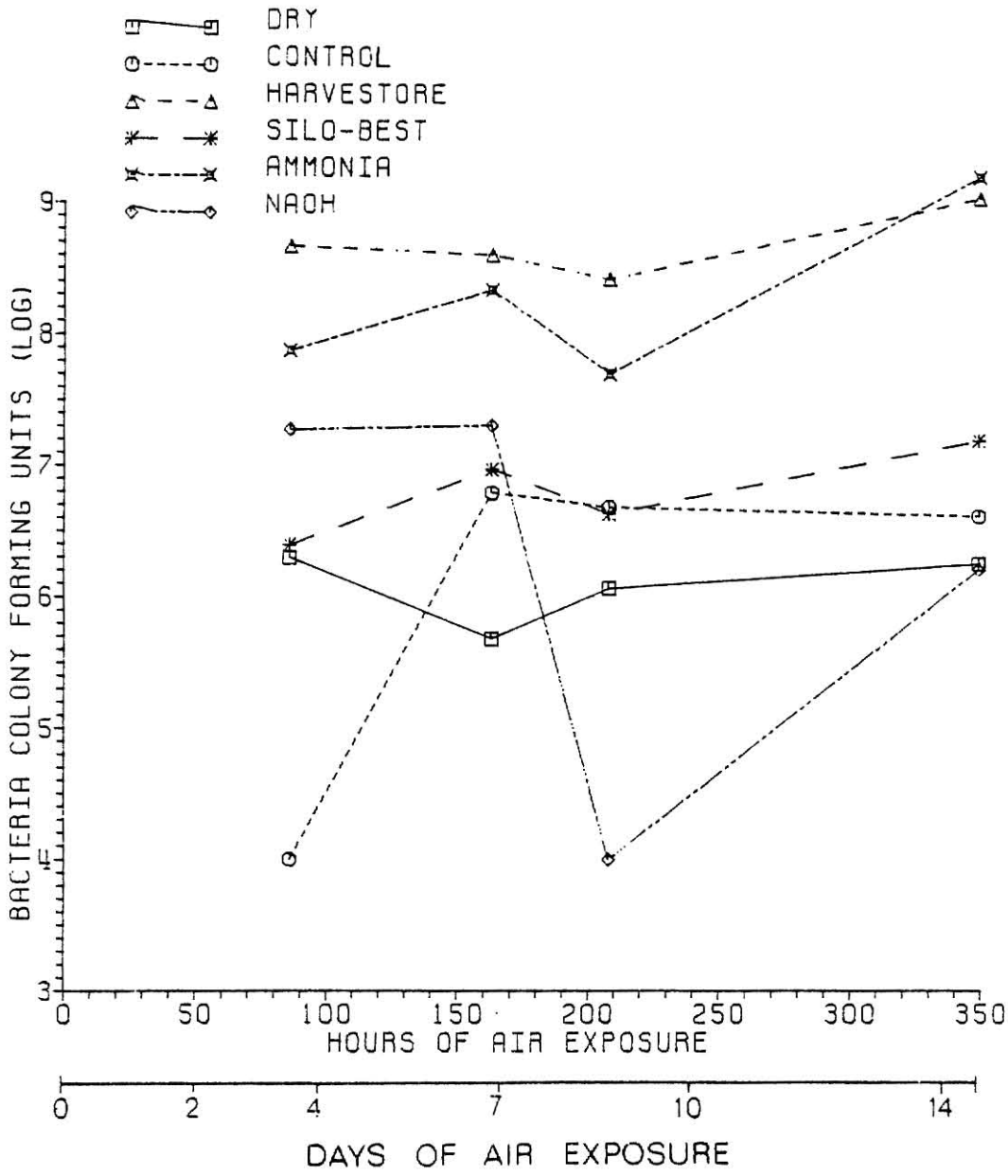

Figure 7. Replication 1: Mold colony forming units.

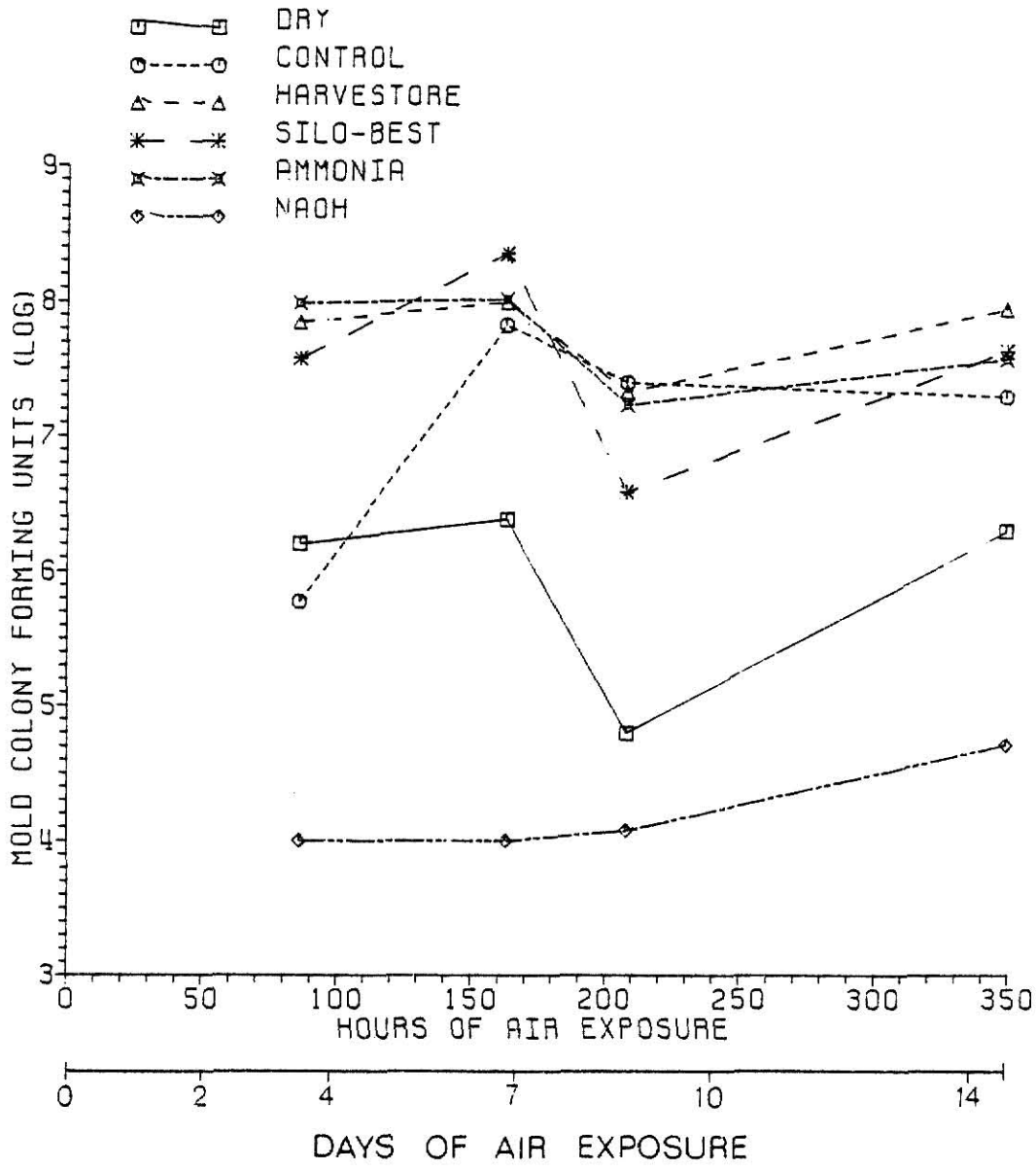

Figure 8. Replication 2: Mold colony forming units.

showing increased bacterial numbers with length of storage when HMC was treated with ammonia. Bacteria counts were generally high in the NaOH corn, except at h 208 in replication 2.

Mold counts for dry and NaOH corns were low for the duration of replications 1 and 2 (figures 7 and 8). Mold counts increased for control and Silo-Best corns after 50 h of air exposure in replication 1. When mold counts were taken in replication 2 (at 86 h), ammonia, Harvestore, and Silo-Best HMC had high counts; control corn counts were high at 163 h. In this study, DM losses closely paralleled the increases in corn temperatures in both replications. This was particularly evident in the Harvestore and ammonia HMC which were the least stable corn treatments. In general, DM losses increased as corn temperature and mold colony counts increased.

Losses of DM and changes in chemical composition over h for the corn treatments in replications 1 and 2 are shown in tables 10 and 11, respectively. Henderson et al., (1979) and Rees (1982) have shown that pH rise, maximum temperature, and accumulated temperature above ambient are correlated with DM losses. Honig and Woolford (1980) have also shown that temperature rise is positively associated with the DM content of the silage, because the moisture can act as a heat sink and reduce temperature elevations.

The changes in pH, lactic and total acids, and total nitrogen as the corn treatments were exposed to air generally agree with previous results (Ohyama et al., 1975; Honig and Woolford, 1980; Henderson et al., 1979). As length of air exposure increased, pH increased for all HMC, including the NaOH treated corn, and lactic and total acids decreased. The losses of fermentation acids were more rapid and extensive in the less stable Harvestore and ammonia corns; however, control and Silo-Best corns also had large losses of fermentation acids by the end of each replication. Ammonia nitrogen, as a percent of total nitrogen, had the greatest increase for the unstable Harvestore corn (2.59 to 7.04 and 5.84 to 9.63 for periods 1 and 2, respectively). The main sources of energy for the

TABLE 10. LOSSES OF DRY MATTER AND SELECTED CHANGES IN CHEMICAL COMPOSITION OF THE SIX CORN TREATMENTS IN THE AEROBIC STABILITY TRIAL (REPLICATION 1)

Corn treatment and item	Hours of air exposure				
	0	48	112	160	340
Dry:					
DM losses	--	1.11	1.12	1.00	.94
pH	5.53	5.55	5.97	5.50	5.66
Lactic acid	.12	.05	.06	.05	.04
Total acids	.27	.15	.14	.15	.11
Total N	1.56	1.55	1.55	1.51	1.56
Control:					
DM losses	--	.89	1.31	1.58	2.74
pH	4.72	4.87	5.26	5.73	5.99
Lactic acid	.32	.40	.34	.24	.13
Total acids	.67	.61	.45	.33	.22
Total N	1.37	1.50	1.45	1.44	1.46
Harvestore:					
DM losses	--	1.67	2.26	3.57	11.78
pH	5.14	5.78	6.37	6.37	6.19
Lactic acid	.30	.27	.14	.13	.11
Total acids	.65	.37	.25	.22	.19
Total N	1.50	1.60	1.52	1.59	1.65
Silo-Best:					
DM losses	--	.76	1.07	1.21	3.64
pH	4.87	4.95	5.09	5.32	5.88
Lactic acid	.23	.21	.26	.19	.08
Total acids	.53	.48	.44	.29	.14
Total N	1.42	1.46	1.43	1.47	1.47
Ammonia:					
DM losses	--	13.43	14.32	16.65	26.70
pH	5.61	5.92	6.80	6.67	6.59
Lactic acid	.85	.72	.43	.41	.15
Total acids	1.06	.90	.53	.51	.26
Total N	1.54	1.62	1.62	1.75	1.96
NaOH:					
DM losses	--	1.15	1.62	1.82	2.08
pH	8.83	9.03	9.15	9.11	9.19
Lactic acid	.06	.06	.07	.08	.06
Total acids	.62	.58	.56	.72	.43
Total N	1.38	1.44	1.36	1.41	1.42

TABLE 11. LOSSES OF DRY MATTER AND SELECTED CHANGES IN CHEMICAL COMPOSITION OF THE SIX CORN TREATMENTS IN THE AEROBIC STABILITY TRIAL (REPLICATION 2)

Corn treatment and item	Hours of air exposure				
	0	86	163	208	349
Dry:					
DM losses	--	-.05	-.29	-.24	-.47
pH	5.80	5.62	5.56	5.51	5.48
Lactic acid	.09	.07	.09	.08	.08
Total acids	.19	.21	.17	.19	.20
Total N	1.53	1.57	1.53	1.59	1.56
Control:					
DM losses	--	2.69	3.05	3.17	2.77
pH	5.08	5.01	5.63	6.03	6.07
Lactic acid	.25	.39	.30	.18	.16
Total acids	.35	.53	.41	.29	.24
Total N	1.45	1.55	1.54	1.55	1.57
Harvestore:					
DM losses	--	3.88	7.78	10.40	15.27
pH	5.76	6.65	6.54	6.48	6.74
Lactic acid	.27	.14	.15	.14	.10
Total acids	.41	.27	.30	.28	.21
Total N	1.28	1.65	1.71	1.70	1.78
Silo-Best:					
DM losses	--	.84	1.70	2.19	4.04
pH	5.26	5.25	6.27	6.21	6.08
Lactic acid	.32	.39	.18	.16	.15
Total acids	.47	.49	.29	.23	.19
Total N	1.64	1.51	1.51	1.57	1.55
Ammonia:					
DM losses	--	1.50	5.46	9.79	14.43
pH	5.13	6.08	6.61	6.43	6.69
Lactic acid	1.31	.77	.30	.25	.26
Total acids	1.43	.88	.44	.34	.37
Total N	2.12	1.56	1.68	1.67	1.78
NaOH:					
DM losses	--	.30	-.43	-.52	-1.53
pH	8.35	8.67	8.76	8.52	8.87
Lactic acid	.06	.13	.12	.14	.13
Total acids	.40	.79	.77	.85	.71
Total N	1.55	1.37	1.41	1.42	1.34

micro-organisms involved in silage deterioration are lactic and acetic acids plus soluble carbohydrates. The metabolism of these acids is responsible for the increase in pH as deterioration proceeds (McDonald, 1981).

Particle Size Determination: Significant differences occurred among the corn treatments for geometric mean particle size, surface area, and particles/g (tables 12, 13 and 14). Since NaOH corn was treated, ensiled, and fed whole; it had the largest ($P<.05$) geometric mean particle size, the smallest ($P<.05$) surface area, and the fewest particles/g. The control HMC had the smallest geometric mean particle size, the largest surface area ($P<.05$), and the second largest number of particles/g. The Harvestore HMC, which was rolled prior to feeding, had the greatest variation in particle size with visual observation indicating a range from very fine flour to half kernel fragments. Harvestore HMC had the largest number of particles/g, which was significantly higher ($P<.05$) than all other corn treatments, except the control. There were no significant differences in particles/g among dry, Silo-Best, ammonia, and NaOH corns.

The particle size determination procedure used was that of Pfost et al. (1976). It is similar to the procedure reported by Ensor et al. (1970), which was recommended for use with HMC by the Standard Procedures Committee at the High Moisture Grains Symposium at Oklahoma State University, Stillwater (Gill et al., 1976).

Galyean et al. (1979) and Sharp et al. (1982) compared digestion of whole kernel dry corn and ground dry corn. Galyean et al. (1979) studied the site and extent of digestion by steers as influenced by corn particle size. Geometric mean diameters of the four corns were: whole grain 5978 microns; and three ground grains, 509, 588, and 832 microns. They concluded that whole corn diets had lower DM, organic matter, and starch digestibilities in the rumen than ground corn diets. Sharp et al. (1982) used whole corn and ground corn (geometric mean diameter of 447 microns) and found that ruminal digestion by steers of the whole corn diet exceeded that of the ground corn diet. In each of these studies, steers

TABLE 12. THE GEOMETRIC MEAN PARTICLE SIZES BY WEIGHT DISTRIBUTION FOR THE SIX CORN TREATMENTS[1]

Replication	Dry	Control	Harvestore	Silo-Best	Ammonia	NaOH
1	3242	2634	3742	2737	3142	5192
2	2945	2634	4007	3076	3145	5472
3	3211	2445	4158	2865	2988	4892
Means	3133 ^{c}	2571 ^{d}	3969 ^{b}	2893 ^{cd}	3092 ^{c}	5185 ^{a}
± SEM	94	63	122	99	52	18

[1] Diameter in microns.

^{a,b,c,d} Values with unlike superscripts differ significantly (P<.05).

TABLE 13. SURFACE AREA FOR THE SIX CORN TREATMENTS[1]

Replication	Dry	Control	Harvestore	Silo-Best	Ammonia	NaOH
1	17.3	26.4	23.5	24.2	18.5	10.1
2	19.8	26.2	21.1	19.6	18.5	9.3
3	17.8	29.6	19.2	22.9	20.9	11.1
Means	18.3 ^{c}	27.4 ^{a}	21.3 ^{bc}	22.2 ^{b}	19.3 ^{bc}	10.2 ^{d}
± SEM	.8	1.1	1.2	1.4	.8	.5

[1] cm^2/g.

^{a,b,c,d} Values with unlike superscripts differ significantly (P<.05).

TABLE 14. THE NUMBER OF PARTICLES/G FOR THE SIX CORN TREATMENTS

Replication	Dry	Control	Harvestore	Silo-Best	Ammonia	NaOH
1	146	1907	5564	1087	219	20
2	280	1818	3130	332	226	12
3	182	3372	1690	882	494	33
Means	202 ^{b}	2366 ^{a}	3461 ^{a}	767 ^{b}	313 ^{b}	22 ^{b}
± SEM	40	504	1130	225	91	6

^{a,b} Values with unlike superscripts differ significantly (P<.05).

received small amounts of feed at intervals not exceeding 3 hours.

The corn particle sizes for the corn treatments in this trial were not associated positively or negatively with cattle performance. This is in agreement with data by Gill et al. (1982) who reported that particle size had little effect on the feeding value of HMC. The geometric mean particle sizes for the six corn treatments compared here were five times the geometric mean particle size reported by Galyean et al. (1979) and Sharp et al. (1982). However, they were similar to the particle size for dry cracked corn reported by Turgeon and Brink (1980).

Results of these investigations into the feeding values of additive treated, chemically treated, and conventionally processed HMC show that granular NaOH (40 g/kg) additions to whole HMC prior to ensiling did not improve cattle performance or diet digestibilities by lambs. Reduced digestibility of crude protein and adverse effects of high sodium intake on rumen digestion may partially explain lower animal performance compared with dry and control HMC diets.

Addition of anhydrous ammonia to cracked HMC prior to ensiling by the Cold-flo process was unsuccessful because only 12% of the added nitrogen was retained for feeding. The resulting low crude protein value of the ammonia HMC diet may explain the poor cattle performance compared with dry and control HMC diets.

The Silo-Best HMC diet was not statistically superior to the dry or control HMC diets; however, there was a consistent trend in the Cattle Feeding Trials and lamb digestion trial for Silo-Best HMC to have an improved feeding value. This agrees with earlier results of Bolsen et al. (1980).

Harvestore stored HMC had the best feed/gain ratio in the Cattle Feeding Trial; however, apparent digestion coefficients from the Lamb Digestion Trial did not agree with the cattle response. Control HMC did not show an advantage to dry rolled corn in the Cattle Feeding Trial.

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APPENDIX TABLES

APPENDIX TABLE 1. ANALYSIS OF VARIANCE FOR pH IN THE RUMEN FERMENTATION TRIAL

Source of variation	Degrees of freedom	Mean square	F	P
Whole plot				
Treatment	5	.2348	.43	.8168
Error[a]	12	.5394		
Sub-plot				
Day	2	2.1382	13.77	.0001
Treatment*day	10	.2391	1.54	.1858
Error[b]	24	.1553		
Sub-sub-plot				
Hour	2	.8848	16.78	.0001
Treatment*hour	10	.0549	1.04	.4191
Day*hour	4	.0828	1.57	.1917
Treatment*day*hour	20	.0463	.88	.6129
Error	72	.0527		

[a] Animal within treatment used as error term.
[b] Animal by day within treatment used as error term.

APPENDIX TABLE 2. ANALYSIS OF VARIANCE FOR PROPIONIC ACID IN THE RUMEN FERMENTATION TRIAL

Source of variation	Degrees of freedom	Mean square	F	P
Whole plot				
Treatment	5	385.8799	1.30	.3268
Error[a]	12	296.7369		
Sub-plot				
Day	2	654.2722	6.81	.0045
Treatment*day	10	19.5507	.20	.9939
Error[b]	24	96.0839		
Sub-sub-plot				
Hour	2	3.4634	.18	.8353
Treatment*hour	10	18.4235	.96	.4854
Day*hour	4	8.2852	.43	.7853
Treatment*day*hour	20	22.4132	1.17	.3068
Error	72	19.1931		

[a] Animal within treatment used as error term.
[b] Animal by day within treatment used as error term.

APPENDIX TABLE 3. ANALYSIS OF VARIANCE FOR ACETIC ACID IN THE RUMEN FERMENTATION TRIAL

Source of variation	Degrees of freedom	Mean square	F	
Whole plot				
Treatment	5	99.1619	1.01	.4530
Error[a]	12	98.1606		
Sub-plot				
Day	2	603.5309	13.52	.0001
Treatment*day	10	11.3696	.25	.9856
Error[b]	24	44.6473		
Sub-sub-plot				
Hour	2	24.0801	2.81	.0667
Treatment*hour	10	6.8543	.79	.6354
Day*hour	4	4.1434	.48	.7507
Treatment*day*hour	20	10.8396	1.25	.2388
Error	72	8.6427		

[a] Animal within treatment used as error term.
[b] Animal by day within treatment used as error term.

APPENDIX TABLE 4. ANALYSIS OF VARIANCE FOR THE RATIO OF ACETIC TO PROPIONIC ACIDS IN THE RUMEN FERMENTATION TRIAL

Source of variation	Degrees of freedom	Mean square	F	P
Whole plot				
Treatment	5	.8896	.98	.4681
Error[a]	12	.9070		
Sub-plot				
Day	2	2.4357	7.56	.0028
Treatment*day	10	.1141	.35	.9547
Error[b]	24	.3220		
Sub-sub-plot				
Hour	2	.0122	.20	.8220
Treatment*hour	10	.0772	1.25	.2775
Day*hour	4	.0270	.44	.7824
Treatment*day*hour	20	.0663	1.07	.3994
Error	72	.0620		

[a] Animal within treatment used as error term.
[b] Animal by day within treatment used as error term.

APPENDIX TABLE 5. ANALYSIS OF VARIANCE FOR ISOBUTYRIC ACID IN THE RUMEN FERMENTATION TRIAL

Source of variation	Degrees of freedom	Mean square	F	P
Whole plot				
Treatment	5	.6044	.73	.6169
Error[a]	12	.8322		
Sub-plot				
Day	2	.2056	.49	.6198
Treatment*day	10	.1163	.28	.9808
Error[b]	24	.4213		
Sub-sub-plot				
Hour	2	.1502	.45	.6389
Treatment*hour	10	.2660	.80	.6308
Day*hour	4	.1127	.34	.8512
Treatment*day*hour	20	.1935	.58	.9165
Error	72	.3331		

[a] Animal within treatment used as error term.
[b] Animal by day within treatment used as error term.

APPENDIX TABLE 6. ANALYSIS OF VARIANCE FOR BUTYRIC ACID IN THE RUMEN FERMENTATION TRIAL

Source of variation	Degrees of freedom	Mean square	F	P
Whole plot				
Treatment	5	78.7925	2.20	.1226
Error[a]	12	35.8745		
Sub-plot				
Day	2	16.3336	.69	.5115
Treatment*day	10	17.4434	.74	.6844
Error[b]	24	23.6918		
Sub-sub-plot				
Hour	2	8.1515	4.47	.0148
Treatment*hour	10	2.4597	1.35	.2223
Day*hour	4	1.2912	.71	.5393
Treatment*day*hour	20	1.9161	1.05	.4191
Error	72	1.8246		

[a] Animal within treatment used as error term.
[b] Animal by day within treatment used as error term.

APPENDIX TABLE 7. ANALYSIS OF VARIANCE FOR ISOVALERIC ACID IN THE RUMEN FERMENTATION TRIAL

Source of variation	Degrees of freedom	Mean square	F	P
Whole plot				
Treatment	5	3.0489	.96	.4767
Error[a]	12	3.1617		
Sub-plot				
Day	2	5.2958	4.66	.0195
Treatment*day	10	.7242	.64	.7677
Error[b]	24	1.1359		
Sub-sub-plot				
Hour	2	.8074	4.97	.0095
Treatment*hour	10	.1836	1.13	.7677
Day*hour	4	.2377	1.46	.2219
Treatment*day*hour	20	.1643	1.01	.4592
Error	72	.1623		

[a] Animal within treatment used as error term.
[b] Animal by day within treatment used as error term.

APPENDIX TABLE 8. ANALYSIS OF VARIANCE FOR VALERIC ACID IN THE RUMEN FERMENTATION TRIAL

Source of variation	Degrees of freedom	Mean square	F	P
Whole plot				
Treatment	5	.6375	1.28	.3360
Error[a]	12	.4997		
Sub-plot				
Day	2	.1367	.33	.7253
Treatment*day	10	.5159	1.23	.3232
Error[b]	24	.4200		
Sub-sub-plot				
Hour	2	.1332	2.69	.0744
Treatment*hour	10	.0310	.63	.7864
Day*hour	4	.2196	4.44	.0029
Treatment*day*hour	20	.0312	.63	.8760
Error	72	.0494		

[a] Animal within treatment used as error term.
[b] Animal by day within treatment used as error term.

APPENDIX TABLE 9. ANALYSIS OF VARIANCE FOR LACTIC ACID IN THE RUMEN FERMENTATION TRIAL

Source of variation	Degrees of freedom	Mean square	F	P
Whole plot				
Treatment	5	16383	2.09	.1373
Error[a]	12	7843		
Sub-plot				
Day	2	412934	69.33	.0001
Treatment*day	10	7417	1.25	.3137
Error[b]	24	5956		
Sub-sub-plot				
Hour	2	55701	11.57	.0001
Treatment*hour	10	6648	1.38	.2066
Day*hour	4	51526	10.70	.0001
Treatment*day*hour	20	4985	1.04	.4344
Error	72	4814		

[a] Animal within treatment used as error term.
[b] Animal by day within treatment used as error term.

APPENDIX TABLE 10. ANALYSIS OF VARIANCE FOR AMMONIA CONCENTRATIONS IN THE RUMEN FERMENTATION TRIAL

Source of variation	Degrees of freedom	Mean square	F	P
Whole plot				
Treatment	5	6496	1.92	.1646
Error[a]	12	3385		
Sub-plot				
Day	2	34569	11.22	.0004
Treatment*day	10	1362	.44	.9104
Error[b]	24	3082		
Sub-sub-plot				
Hour	2	44011	25.06	.0001
Treatment*hour	10	607	.35	.9649
Day*hour	4	643	.37	.8319
Treatment*day*hour	20	1398	.80	.7098
Error	72	1796		

[a] Animal within treatment used as error term.
[b] Animal by day within treatment used as error term.

APPENDIX TABLE 11. RUMEN PH MEANS OVER HOURS AND OVER DAYS

Hour	May 10	June 7	July 5	Mean[a]	SEM
1	6.1	6.0	6.3	6.1	± .1
3	6.2	5.9	6.3	6.1	± .1
5	6.3	6.1	6.6	6.3	± <.1
Mean[a] ± SEM	6.2 .1	6.0 <.1	6.4 .1		

[a] Each value represents the mean ± SE of 54 observations.

APPENDIX TABLE 12. MOLAR PROPORTION OF VALERIC ACID MEANS OVER HOURS AND OVER DAYS

Hour	May 10	June 7	July 5	Mean[a]	SEM
1	1.0	.8	1.1	1.0	± .1
3	1.0	1.1	1.1	1.0	± .1
5	1.0	1.1	1.0	1.0	± .1
Mean[a] ± SEM	1.0 .1	1.0 <.1	1.1 .1		

[a] Each value represents the mean ± SE of 54 observations.

APPENDIX TABLE 13. MOLAR PROPORTION OF PROPIONIC ACID MEANS BY DAYS AVERAGED OVER HOURS

Day	Dry	Control	Harvestore	Silo-Best	Ammonia	NaOH
May 10	51.6	45.9	52.1	50.4	49.1	41.7
June 7	47.9	42.0	48.3	45.6	46.1	37.4
July 5	41.4	36.6	46.7	44.1	42.3	38.0
Mean[a]	47.0	41.5	49.0	46.7	45.8	39.1
± SEM	1.0	2.2	1.1	1.6	1.1	1.6

[a] Each value represents the mean ± SE of 27 observations.

APPENDIX TABLE 14. MOLAR PROPORTION OF ACETIC ACID MEANS BY DAYS AVERAGED OVER HOURS

Day	Dry	Control	Harvestore	Silo-Best	Ammonia	NaOH
May 10	41.9	42.0	39.0	41.9	41.6	44.2
June 7	44.5	47.4	45.4	45.3	45.3	49.5
July 5	46.9	51.1	44.8	46.6	48.9	51.6
Mean[a]	44.4	46.8	43.1	44.6	45.3	48.5
± SEM	.6	1.4	.9	1.1	.8	1.2

[a] Each value represents the mean ± SE of 27 observations.

APPENDIX TABLE 15. MOLAR PROPORTION RATIOS OF ACETIC TO PROPIONIC MEANS OVER HOURS AND OVER DAYS

Hour	May 10	June 7	July 5	Mean[a]
1	.9	1.1	1.3	1.1
3	.9	1.1	1.3	1.1
5	.9	1.1	1.3	1.1
Mean[a]	.9	1.1	1.3	

[a] Each value represents the mean of 54 observations.

APPENDIX TABLE 16. MOLAR PROPORTION OF BUTYRIC ACID MEANS BY HOURS AVERAGED OVER DAYS

Hour	Dry	Control	Harvestore	Silo-Best	Ammonia	NaOH
1	5.6	7.9	5.9	5.3	6.5	9.1
3	5.6	8.1	5.0	6.5	6.2	9.5
5	5.4	9.2	5.7	7.1	6.7	10.6
Mean[a]	5.5	8.4	5.6	6.3	6.5	9.8
± SEM	.4	.8	.5	.7	.4	.6

[a] Each value represents the mean ± SE of 27 observations.

APPENDIX TABLE 17. MOLAR PROPORTION OF BUTYRIC ACID MEANS BY DAYS AVERAGED OVER HOURS

Day	Dry	Control	Harvestore	Silo-Best	Ammonia	NaOH
May 10	4.2	9.1	7.0	5.8	7.4	11.2
June 7	4.6	7.0	3.9	6.7	6.0	10.1
July 5	7.8	9.2	5.8	6.4	6.0	8.0
Mean[a]	5.5	8.4	5.6	6.3	6.5	9.8
± SEM	.4	.8	.5	.7	.4	.6

[a] Each value represents the mean ± SE of 27 observations.

APPENDIX TABLE 18. RUMEN AMMONIA CONCENTRATION MEANS BY DAYS AVERAGED OVER HOURS

Day	Dry	Control	Harvestore	Silo-Best	Ammonia	NaOH
May 10	5.3	5.1	7.3	8.3	4.3	6.6
June 7	6.3	8.8	11.6	7.9	6.2	9.3
July 5	12.0	10.7	22.7	11.8	7.5	13.2
Mean[b]	7.9	8.2	10.3	9.3	6.0	9.7
± SEM	.9	1.1	.8	1.0	1.2	1.2

[a] Mg/dl.
[b] Each value represents the mean ± SE of 27 observations.

APPENDIX TABLE 19. RUMEN AMMONIA CONCENTRATION MEANS OVER HOURS AND OVER DAYS

Hours	May 10	June 7	July 5	Mean[b]	SEM
1	9.5	11.2	14.8	11.8	± .9
3	4.5	7.3	10.3	7.4	± .7
5	4.5	6.5	8.4	6.5	± .4
Mean[b]	6.2	8.3	11.2		
± SEM	.5	.6	.9		

[a] Mg/dl.
[b] Each value represents the mean ± SE of 54 observations.

APPENDIX TABLE 20. DAILY INTAKE, APPARENT DIGESTIBILITY, AND NITROGEN BALANCE FOR THE DRY CORN DIET IN THE LAMB DIGESTION TRIAL

	Period 1			Period 2		
	Lamb 1	Lamb 2	Lamb 3	Lamb 1	Lamb 2	Lamb 3
Diet crude protein, %	13.1	13.1	13.1	12.9	12.9	12.9
Dry matter intake, g/d	1065.0	1065.0	1013.3	1081.7	1081.7	1081.7
	% Apparent digestibility					
Dry matter	74.3	82.1	81.8	83.8	79.0	81.9
Organic matter	75.8	83.0	83.1	85.0	80.4	83.0
Ash	48.7	66.6	57.6	59.0	52.8	61.2
Crude protein	42.3	75.3	72.8	80.2	71.1	76.5
	Nitrogen balance					
N intake, g/d	22.4	22.4	21.0	22.5	22.5	22.5
N retained, g/d	-2.2	2.3	7.7	4.9	4.2	6.0
N retained, as % of N intake	-9.7	10.3	36.8	21.7	18.8	27.0
N retained, as % of absorbed N	-23.0	13.7	50.6	27.0	26.4	35.3

APPENDIX TABLE 21. DAILY INTAKE, APPARENT DIGESTIBILITY, AND NITROGEN BALANCE FOR THE CONTROL CORN DIET IN THE LAMB DIGESTION TRIAL

	Period 1			Period 2		
	Lamb 1	Lamb 2	Lamb 3	Lamb 1*	Lamb 2	Lamb 3*
Diet crude protein, %	11.8	11.8	11.8	12.9	12.9	12.9
Dry matter intake, g/d	1170.9	1170.9	1170.9	---	1188.6	---
	% Apparent digestibility					
Dry matter	83.4	83.1	82.3	--.	79.9	--.
Organic matter	84.4	84.2	83.6	--.	81.0	--.
Ash	62.8	60.2	54.1	--.	58.1	--.
Crude protein	67.6	68.3	67.3	--.	72.7	--.
	Nitrogen balance					
N intake, g/d	22.1	22.1	22.1	--.	24.3	--.
N retained, g/d	5.3	7.1	2.8	-.	8.9	-.
N retained, as % of N intake	23.9	32.0	12.8	--.	36.5	--.
N retained, as % of absorbed N	35.4	46.8	19.0	--.	50.2	--.

* Lambs 1 and 3 went off-feed and failed to consume the diet.

APPENDIX TABLE 22. DAILY INTAKE, APPARENT DIGESTIBILITY, AND NITROGEN BALANCE FOR THE HARVESTORE CORN DIET IN THE LAMB DIGESTION TRIAL

	Period 1			Period 2		
	Lamb 1	Lamb 2	Lamb 3	Lamb 1	Lamb 2	Lamb 3
Diet crude protein, %	12.4	12.4	12.4	12.8	12.8	12.8
Dry matter intake, g/d	1132.3	1132.3	1132.3	1203.2	1203.2	1203.2
	% Apparent digestibility					
Dry matter	85.9	79.3	83.3	79.7	75.5	73.1
Organic matter	86.6	80.9	84.3	81.0	77.1	74.4
Ash	72.8	47.5	63.4	53.9	43.3	46.9
Crude protein	78.0	66.4	75.6	72.7	66.4	61.7
	Nitrogen balance					
N intake, g/d	22.5	22.5	22.5	24.4	24.4	24.4
N retained, g/d	6.6	7.3	6.6	7.7	4.3	9.3
N retained, as % of N intake	29.4	32.4	29.2	31.7	17.6	38.0
N retained, as % of absorbed N	37.7	48.9	38.7	43.6	26.4	61.5

APPENDIX TABLE 23. DAILY INTAKE, APPARENT DIGESTIBILITY, AND NITROGEN BALANCE FOR THE SILO-BEST CORN DIET IN THE LAMB DIGESTION TRIAL

	Period 1			Period 2		
	Lamb 1	Lamb 2	Lamb 3	Lamb 1	Lamb 2	Lamb 3
Diet crude protein, %	12.4	12.4	12.4	12.4	12.4	12.4
Dry matter intake, g/d	1186.9	1186.9	1186.9	1226.5	1226.5	1203.1
	% Apparent digestibility					
Dry matter	81.6	82.6	81.6	82.6	82.9	85.0
Organic matter	82.9	83.4	82.9	84.0	84.1	85.9
Ash	56.0	64.8	55.1	53.4	57.1	67.6
Crude protein	71.8	73.5	70.7	70.3	74.0	74.9
	Nitrogen balance					
N intake, g/d	23.4	23.4	23.4	24.0	24.0	22.3
N retained, g/d	6.1	8.0	7.5	5.6	8.0	8.8
N retained, as % of N intake	26.1	34.0	32.1	23.5	33.1	39.2
N retained, as % of absorbed N	36.3	46.2	45.4	33.4	44.8	52.4

APPENDIX TABLE 24. DAILY INTAKE, APPARENT DIGESTIBILITY, AND NITROGEN BALANCE FOR THE AMMONIA CORN DIET IN THE LAMB DIGESTION TRIAL

	Period 1			Period 2		
	Lamb 1	Lamb 2	Lamb 3	Lamb 1	Lamb 2	Lamb 3
Diet crude protein, %	11.9	11.9	11.9	11.7	11.7	11.7
Dry matter intake, g/d	1141.5	1141.5	1141.5	1203.1	1203.1	1203.1
	% Apparent digestibility					
Dry matter	81.1	81.9	81.7	85.0	75.3	81.5
Organic matter	82.2	83.4	82.7	85.9	76.2	82.6
Ash	59.3	52.4	61.2	67.6	56.9	59.0
Crude protein	68.6	67.1	68.4	74.9	66.4	70.5
	Nitrogen balance					
N intake, g/d	21.8	21.8	21.8	22.3	22.3	22.3
N retained, g/d	6.3	6.4	6.8	8.8	6.1	3.9
N retained, as % of N intake	28.9	29.6	31.3	39.2	27.1	17.5
N retained, as % of absorbed N	42.2	44.1	45.8	52.4	40.9	24.7

APPENDIX TABLE 25. DAILY INTAKE, APPARENT DIGESTIBILITY, AND NITROGEN BALANCE FOR THE NaOH CORN DIET IN THE LAMB DIGESTION TRIAL

	Period 1			Period 2		
	Lamb 1	Lamb 2	Lamb 3	Lamb 1	Lamb 2	Lamb 3
Diet crude protein, %	12.0	12.0	12.0	11.5	11.5	11.5
Dry matter intake, g/d	1174.6	1174.6	1174.6	1280.9	1280.9	1280.9
	% Apparent digestibility					
Dry matter	76.5	75.2	83.1	76.7	79.9	77.4
Organic matter	77.2	75.6	83.4	77.0	80.1	77.9
Ash	68.1	69.9	79.6	71.7	74.4	71.1
Crude protein	59.6	45.6	61.2	49.3	53.2	47.8
	Nitrogen balance					
N intake, g/d	22.4	22.4	22.4	22.9	22.9	22.9
N retained, g/d	8.7	6.3	7.3	6.7	6.7	3.6
N retained, as % of N intake	38.5	27.9	32.4	29.3	29.3	15.7
N retained, as % of absorbed N	64.7	61.2	53.0	59.4	55.0	32.8

TABLE 26. ANALYSIS OF VARIANCE FOR APPARENT ASH DIGESTIBILITY IN THE LAMB DIGESTION TRIAL

Source of variation	Degrees of freedom	Mean square	F	P
Treatment	5	87.33	3.22	.06
Period	1	40.67	1.50	.25
Lamb	17	51.78	1.91	.16
Error	9	27.13		

TABLE 27. ANALYSIS OF VARIANCE FOR APPARENT CRUDE PROTEIN DIGESTIBILITY IN THE LAMB DIGESTION TRIAL

Source of variation	Degrees of freedom	Mean square	F	P
Treatment	5	277.20	4.66	.02
Period	1	38.91	.65	.44
Lamb	17	52.11	.88	.61
Error	9	59.46		

TABLE 28. ANALYSIS OF VARIANCE FOR APPARENT ORGANIC MATTER DIGESTIBILITY IN THE LAMB DIGESTION TRIAL

Source of variation	Degrees of freedom	Mean square	F	P
Treatment	5	11.17	.75	.61
Period	1	4.98	.33	.58
Lamb	17	6.29	.42	.94
Error	9	14.88		

TABLE 29. ANALYSIS OF VARIANCE FOR APPARENT DRY MATTER DIGESTIBILITY IN THE LAMB DIGESTION TRIAL

Source of variation	Degrees of freedom	Mean square	F	P
Treatment	5	9.08	.61	.70
Period	1	5.64	.38	.56
Lamb	17	7.20	.48	.91
Error	9	14.97		

TABLE 30. ANALYSIS OF VARIANCE FOR NITROGEN RETENTION IN THE LAMB DIGESTION TRIAL

Source of variation	Degrees of freedom	Mean square	F	P
Treatment	5	5.63	1.61	.25
Period	1	3.53	1.01	.34
Lamb	17	5.40	1.55	.26
Error	9	3.49		

TABLE 31. ANALYSIS OF VARIANCE FOR NITROGEN RETENTION AS A % OF NITROGEN INTAKE IN THE LAMB DIGESTION TRIAL

Source of variation	Degrees of freedom	Mean square	F	P
Treatment	5	.008	1.19	.39
Period	1	.003	.38	.56
Lamb	17	.001	1.46	.29
Error	9	.007		

TABLE 32. ANALYSIS OF VARIANCE FOR NITROGEN ABSORBED AS A % OF NITROGEN INTAKE IN THE LAMB DIGESTION TRIAL

Source of variation	Degrees of freedom	Mean square	F	P
Treatment	5	.010	1.89	.19
Period	1	.007	.48	.50
Lamb	17	.001	1.62	.23
Error	9	.015		

HIGH MOISTURE CORN WITH ADDITIVES FOR CATTLE FINISHING DIETS

by

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B.S., Kansas State University, 1974

AN ABSTRACT OF A MASTER'S THESIS

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ABSTRACT

Four concrete stave silos and one oxygen-limiting Harvestore® were used to store high moisture corn (HMC) at 78 to 82% dry matter (DM). Stave silo HMC treatments were: 1) no additive (control); 2) 36.4 kg of NaOH; 3) .92 kg of Silo-Best® (an enzyme additive); and 4) 8.77 kg of Cold-Flo® ammonia. Additive rates were per 909 kg of corn DM. Treatments 5 and 6 were Harvestore HMC and artificially dried corn (dry). NaOH HMC was fed whole; Harvestore and dry corns were coarsely cracked before feeding and the other HMC were coarsely cracked before ensiling. Silos were opened 210 d after filling and a complete mixed diet of each corn was full-fed for 93 d to 78 cattle (five individually fed steers and two pens of four heifers/diet). Diets contained 82.2% of the respective corn, 4.5% forage sorghum silage, 4.5% alfalfa hay and 7.8% supplement (DM basis). Three wether lambs were fed corn diets for a replicated digestion trial.

Recovery of added Cold-Flo nitrogen was only 12%; NaOH caused discoloration and extreme caking of the corn kernels. In the cattle trial, NaOH HMC was used the least efficiently for gain by both steers and heifers and gains were poor for both ammonia and NaOH HMC. Poor performance for NaOH HMC diet was likely related to changes in rumen function due to the high sodium intake. Ammonia HMC diet was deficient in crude protein (CP) because only 12% of the ammonia was recovered from the time of application to the time of feeding. Cattle performance differences did not occur among dry, Harvestore, control, or Silo-Best corn diets; except Harvestore corn had the lowest daily DM intake. Apparent digestion coefficients for CP were significantly less for NaOH HMC, which was probably a result of an increased acid-detergent nitrogen fraction in this corn. Particle size analyses showed differences among corn treatments; however, these differences were not associated with differences in cattle performance or digestion trial results.

Aerobic stability results showed ammonia and Harvestore HMC to be the least stable

in air and to have the largest temperature increases and DM losses. Control and Silo-Best HMC were less stable than dry corn or NaOH HMC.