1966

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Recommended Citation

Mohanty, Guru Prasad, "The Effect of Methods of Storage on The Gross Energy, Chemical Composition and Feeding Value of Alfalfa" (1966). *Theses and Dissertations*. 1258.
http://openprairie.sdstate.edu/etd/1258

THE EFFECT OF METHODS OF STORAGE ON THE GROSS ENERGY, CHEMICAL COMPOSITION AND FEEDING VALUE OF ALFALFA

BY

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A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science, Department of
Dairy Science, South Dakota State
University

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser Date

Head, Dairy Science Department Date

ACKNOWLEDGMENTS

The author would like to express his sincere appreciation to Dr. H. H. Voelker for his assistance, valuable guidance and encouragement during the course of this investigation.

Sincere thanks to Dr. D. F. Breazeale for his comments and directions in the preparation of this thesis.

The generous help of Mr. E. I. Whitehead, and Mr. G. F. Gastler with matters of chemical analysis and procedure are gratefully acknowledged.

Assistance on heifer management and care by LeRoy Twombley, Dale Kurtenbach and others is greatly appreciated.

Sincere appreciation is extended to Frances Wells for typing this thesis.

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INTRODUCTION

Production of good quality hay or silage and its proper storage without loss of the nutritive value is an important problem for dairy farmers. They are particularly interested in meeting the energy needs in feeding their herds for milk production. During the past decade there has been a substantial increase in the volume and intensity of research towards the nutritional and calorimetric aspects of cattle feeds. A number of unavoidable problems come in the way of their application causing financial disaster in today's competitive economy of dairy farming. To increase milk production or to maintain a high level of production, dairy cattle must be provided with high quality forages, but large losses in their feeding value may occur due to problems in cutting, curing, weather conditions and improper storage. It is quite beneficial to store well cured hay in good condition without any loss of nutrients. The cost involved in providing proper storage space for forages required yearly for a large herd of cows is a limiting factor, however, on many farms. In common practice hay fed to dairy cows is sometimes stacked out doors. Such storage exposes hay to weather conditions allowing a series of changes which deteriorate the nutritional value of the forage. This hay demands less price in comparison to hay stored under protected sheds. Devaluation of such alfalfa hay is primarily concerned with bleaching, browning and molding effects during storage.

Previous workers (McCampbell, 1919, Dodd, 1933) noticed equal body weight gains in steers by feeding normal and browned alfalfa hay, but 25% less gain has been observed with black alfalfa hay feeding. In general, clean browned alfalfa hay is very rarely found from out door hay stacks. Mostly mold growth is associated with such storage. No appreciable research has been conducted concerning the effect of molding on the nutritive value of alfalfa hay or silage. This is not only a problem in the United States of America, but is common to the farmers of most countries where extensive dairying is practiced.

An attempt has been made in this research to investigate the feeding value of alfalfa hay stored out doors associated with browning, bleaching and molding. It was also desirable to compare this feeding value with normal well cured alfalfa hay and low moisture alfalfa silage.

Previous research at South Dakota State University indicated that when dairy cattle were fed only alfalfa haylage, they consumed abnormally large amounts of dicalcium phosphate. This research was designed to obtain more information concerning such mineral problems.

REVIEW OF LITERATURE

Effects of different storage methods on nutritive value of alfalfa

The increasingly rapid expansion of nutritional research and knowledge in recent years has resulted in better storage methods for alfalfa and other forages. Advanced research in this field has clearly cited many reasons influencing its nutritional value, but at times differences of opinion and lack of co-ordination occurred between many scientists in this field. For instance - Shepherd, et al. (1946) stated higher nutritive value of wilted silage for dairy cows than barn cured and field cured hay, but Byers (1965) concluded that low moisture silage can not be superior to the feeding value of hay or high moisture silage.

Niedermeier, et al. (1963) compared the nutritive value of alfalfa-brome forage stored as slightly wilted silage, low moisture silage and hay. The group of cows on low moisture alfalfa-brome silage consumed the maximum dry matter, and produced more milk and solids-not-fat than the other two groups. Average daily body weight gain was also more for this group of cows.

Larsen, et al. (1961) observed a higher dry matter consumption by experimental Holstein cows from alfalfa silage than from the hay or haylage groups, but maximum amount of fat-corrected-milk was produced by cows on haylage. Haylage developed a mild fermentation as judged by pH.

Ordinary storage of hay with more than 30% moisture was not safe, because there was chance of spontaneous combustion and the loss of dry matter. Hay turned from brown to black. Heating reduced the digestibility of hay, especially of protein content and increased carotene loss. Chopped hay heated more than long hay at a given temperature. Therefore, storage of long chopped hay was preferable to short chop (Monroe, et al. 1946). They also noticed the loss of dry matter from well cured long hay when it was stored with moisture less than 30%. This loss was mostly of nitrogen-free-extract. They concluded that, proper moisture evaluation was needed to minimize losses of forage in the form of hay or silage.

Moore, et al. (1948) observed greater body weight gain in growing dairy calves on wilted silage than those on field cured or barn-dried hay. Contrary to the above study Sykes, et al. (1955) recommended only alfalfa hay as roughage for satisfactory growth of dairy heifers. They noticed a subnormal gain using wilted alfalfa silage as the only roughage.

When wilted alfalfa silage was compared by Shepherd, et al. (1948) with field-cured and barn-cured alfalfa hay for feeding value and conservation of nutrients, carotene and dry matter content was maximum in barn-dried hay. Milk production was 40% higher in silage and 48% higher in barn-dried-hay-fed groups than the field-dried-hay-fed cows. Field-cured hay was of poor quality due to rain damage. Gordon, et al. (1961) noticed a minimum of 4% stored dry matter loss under the haylage system, but 22-24% dry matter was lost from high moisture direct-cut silage during storage. Haylage excelled high moisture direct-cut silage for animal acceptance, milk production and live weight gain, but not top quality hay. Dry matter consumption was positively correlated with dry matter content of the forage.

Much research has been done on the effect of different levels of moisture in alfalfa during the ensiling process and the type of storage on the final nutritional value of the silage. Byers (1963) observed more dry matter intake and production of more fat-corrected milk from cows on low moisture silage than the group on ordinary silage.

A study of half-dry and slightly wilted silage in gas-tight steel silos by Gordon, et al. (1951) indicated slightly better feeding value on the basis of milk production and body weight maintenance in half-dry-silage-fed cows than the high-moisture silage group. In their experiment sheep could eat high-dry-matter-silage faster than high-moisture silage.

Rogers, et al. (1953) recommended the preparation of silage from forages with more than 40% dry matter. Degree of wilting and stage of growth are important to the kind and qualities of silage.

Silages low in moisture were not particularly well accepted by animals. They used small silos which were not air-tight. This could have added to the low palatability, because of poor preservation.

Gordon, et al. (1958) noticed better live weight gain, daily fat-corrected milk production and dry matter consumption by feeding wilted silage than direct cut silage. When direct-cut forages from the same field were stored in bunker and tower silos, the direct-cut silage produced more body weight gain with more dry matter consumption, while the wilted silage increased daily fat-corrected milk yield.

Haylage was compared to wilted silage in gas tight silos by Shepherd, et al. (1953) and they found the storage losses of dry matter were about 1% in the haylage as compared to 6% in wilted silage. The cows lost weight on high moisture alfalfa silage but gained weight on haylage.

Voelker (1963) conducted feeding trials with dairy cows and heifers with alfalfa haylage stored in gas tight storage and open topped silos. Milk production, dry matter consumption and weight gains were more favorable for haylage in gas tight storage than from haylage in an open tower silo.

By sealing alfalfa haylage, a higher lactic acid content contributed towards its better flavor and aroma, and cows consumed it better than open silo haylage, (Voelker, et al. 1964). They also indicated that the most satisfactory moisture range for haylage is from 28% to 50%, with the best level at 34% moisture. Preservation loss of dry matter was 12.1% in concrete stave silos whereas in gas-tight storage it was 4.9%. Cows produced more milk and maintained better persistency when fed haylage stored in sealed storage.

Many workers have tried different feed additives in order to increase the feeding value of alfalfa silage. Nevens, et al. (1936)

mixed whey powder with alfalfa at the rate of 1, 2, 3, 4 and 5% during the ensiling process. This increased the acid content of silage more than alfalfa without whey powder. Whey powder was a more effective preservative of alfalfa than molasses or lactic acid starter.

Axelsson (1938) reported the effect of adding mineral acids to alfalfa silage. Hydrochloric acid and sulphuric acid could preserve alfalfa silage better than any organic acid. It reduced the loss of nutritive ingredients during storage. Such silages were rich in vitamin A and stimulated milk production. Mineral acids attacked the woody tissue of silages and rendered them more digestible.

Addition of ground corn at the rate of 100 pounds per ton of alfalfa-brome grass increased acetic acid, linolenic acid, protein, fat and nitrogen-free extract content of the resulting silage. Cows showed a distinct preference for such a silage (Allen, et al. 1954). Voelker, et al. (1956) compared the nutritive value of alfalfa silage treated with sodium-metabisulphite and iodized salt. They noticed a higher carotene content and lower pH level of bisulphite-treated-silage than non treated and iodized-salt treated silage. There were no significant differences in milk production among the cows on these silages.

Addition of preservatives like molasses, sugar, sprouted grains and lactobacillus cultures to alfalfa silage caused fastest drop in pH, which remained low throughout the trials (Baker, et al. 1958). Voelker, et al. (1959) observed that preservation losses occurring in alfalfa silages preserved with sodium-metabisulphite depended on air-tighteness, exposed surface, depth of stored silage and moisture content of the crop.

Effect of heating in the bale

Depending on the amount of heat during storage, the color of hay varies from brown to black. Stacked hay retained some green color if no perceptible heat was present. It appeared light brown at 120°F, medium brown at 140°F to 150°F; dark brown at 160°F and more or less charred at about 190°F (Dodd, 1933). Cause of heating in the bale was due to the chemical oxidation process, which was helped by the respiration of the living cells up to 40-45°C, and by the micro-organisms up to 70°C producing unstable and unsaturated compounds. Hay below 30% moisture was considered safe from heating to a destructive dangerous degree, hay with 27% moisture was expected to retain its green color. Green color of hay was destroyed when the heating exceeded 50° C. Clean brown hay was formed between 55°C and 70°C temperature. Hay stored at 40 to 50°C became moldy grayish-brown (Hanson, 1939). Clean brown hay was prepared by heating quickly to 55°C, while prolonged heating at 50°C or less and later heating to above 55°C produced dusty hay.

Cannon, et al. (1937) stated that, the amount of browning varied directly with the moisture content of the plant at the time of storing.

Fred, et al. (1924) produced brown alfalfa hay by wilting to 30-40% moisture and then packing it tightly in the silo with a heavy seal on top. The resulting hay was of high quality, with good odor and was readily eaten by cattle.

Bechtel, et al. (1945) stated that alfalfa containing 30% or more moisture when placed in the mow or stack is likely to become brown during storage.

Hoffman, et al. (1937) noticed a loss of 22% dry matter from brown hay. Fat, sugars and hemicellulose groups were affected. Scurti, et al. (1942) reported the loss of nitrogenous matter and fat in the alfalfa leaf with increasing moisture level, but cellulose and ash content was increased. Spoehr (1926) indicated the decrease in saccharide content of green plants due to high temperature storage, but storage at low temperature increased the monosaccharide level. Dodd (1933) stated that sugars are presumed to be decomposed to glucic acid and other unsaturated compounds due to high temperature during storage. These unite rapidly with oxygen to produce additional heat. Such heat causes black hay to contain more than 50% carbon. Lignin also decomposes the leads to increased heat production.

Storage of alfalfa with varying moisture content from 28 to 70% for 7 to 7½ months caused variable losses in dry matter, ether extract, sugars and hemicellulose. Losses in ether extract were accompanied by complete destruction of carotene. There were some losses of cellulose and crude protein along with other organic constituents, (Hoffman, et al. 1937).

Swanson, et al. (1919) stacked 40 tons of alfalfa containing 59.42% moisture and on opening found hay varying from black to moldy-green in color with 39% loss of organic matter.

Watson (1939) stated that brown hay may resemble normal hay in chemical composition, but loss of organic matter and feeding value depends on the intensity of brown color developed by hay. True protein is more affected than crude protein. Slight heating reduces the apparent digestibility of protein by 50%. In very badly heated hay digestible protein is fully lost.

Laboratory experiments by Guilbert, et al. (1931) indicated a loss of 20-40% dry matter, 30% phosphorus, 20% crude protein and 35% nitrogen-free extract due to leaching by water.

Excessive heating during storage consistently lowered the apparent digestibility of all nutrients except ether extract. Protein was affected more with average digestion coefficients of 67, 16 and 3 in normal, brown and black alfalfa-hay respectively (Bechtel, et al. 1945). Cows fed with heated bales of hay lost considerably in body weight, developed a gaunt appearance and were uneasy. Feces voided by cows on excessively heated hay had a black appearance, contained less than normal moisture and those resulting from black hay were voided in the form of hard, dry and flattened pellets.

McCampbell (1919) conducted a steer feeding trial with normal, brown and black alfalfa hay. Brown and normal hay showed approximately equal daily weight gain, but 25% less gain was found in steers fed with black alfalfa hay. In his second trial, cows consumed 5.5% more grain and produced 4.3% less milk when fed brown hay than on normal green hay.

Palatability

A feeding trial of brown and green alfalfa hay with steers showed equal consumption from both varieties, but less black alfalfa hay was consumed (Swanson, et al. 1919). Livestock feeders reported good results from brown alfalfa hay on the basis of more consumption by animals. This proved the palatability of these materials. On the other hand Reed (1929) and Cannon, et al. (1937) concluded that browning of alfalfa hay in a mow does not make the hay more palatable to dairy cows than green colored alfalfa hay.

Utah workers (Maynard, et al. 1932) conducted lamb feeding experiments with brown alfalfa hay. They stated that excessive heating in a mow or stack results in brown hay which has a pleasant sweet tobacco like aroma, and this may be more palatable to cattle than green hay. They noticed a higher consumption of brown alfalfa hay by cattle with less wastage than green cured alfalfa hay.

Willard (1933) mentioned that alfalfa browned in the stack had retained its palatability, although the sugar content of such hay had been reduced by the browning process. Bechtel, et al. (1945) measured palatability of brown hay by feed intake and refusal. They noticed that brown alfalfa hay was less palatable than normal green hay from the same stack but this brown hay was more palatable than normal green hay from different sources; and apparently contained less protein and more fiber than was originally present in the alfalfa from which brown hay was produced.

Effect of all alfalfa ration on calcium and phosphorus assimilation of dairy animals

Kleiber, et al. (1936) noted remarkable loss in appetite in phosphorus deficiency, but there was a slightly lower efficiency of energy utilization. This raised the question as to whether there is a poorer utilization of the small amount of feed consumed. In studying this problem with dairy cattle Riddell et al. (1934) found that there was no decrease in digestibility, but there was evidence of a higher energy metabolism due to phosphorus deficiency.

Hagg, et al. (1932) conducted a series of metabolism trials with rations consisting of alfalfa hay, with and without supplementation of disodium phosphate, calcium carbonate and bone flour. When fed alfalfa hay without supplements, the cows were always in negative calcium and phosphorus balances. Feeding of disodium phosphate resulted in slightly positive phosphorus balance, but bone flour supplementation caused positive calcium and phosphorus balances. Their analysis of alfalfa showed a calcium content of 1.16% and phosphorus content of .153% of dry matter.

Lamb, et al. (1934) stated that low phosphorus level in rations causes lack of appetite for roughages in animals. They measured the blood calcium and phosphorus level of dairy heifers before calving. Calcium level ranged from 102.0 mg to 10.8 mg per 100 ml of plasma and phosphorus levels were from 6.3 mg to 6.57 mg per 100 ml of plasma. They concluded that 10.81 to 12.25 gms of phosphorus daily can be sufficient for growth and pregnancy from 18 to 30 months of age.

Lewis, et al. (1951) reported that the phosphorus plasma level was related to the phosphorus intake in a general way, but calcium level showed a characteristic fluctuation, which was not affected by treatments or by plasma phosphorus levels.

When alfalfa ash was added to the ration of sheep, dry matter, nitrogen free extract and crude fiber digestibility increased significantly (Swift, et al. 1951).

Addition of 2% lime stone to a mixed ration of grass hay and 16% protein caused depression in the energy utilization and protein digestibility (Colovos, et al. 1958). This was referred to as the effect of wide calcium:phosphorus ratio.

Colovos, et al. (1955) conducted an experiment with 18 to 24 months old heifers by feeding them 2% limestone, 2% dicalcium phosphate, and 2% limestone plus 2% dicalcium phosphate in separate groups. There was a decrease of digestibility in the 2% limestone group. The dicalcium phosphate group did not show any appreciable effect and in the 2% dicalcium phosphate and 2% limestone group dicalcium phosphate minimized the depressing effect of limestone. Excess of calcium depressed body weight gain by interfering with the digestibility or absorption of nutrients and mineral elements other than phosphorus (Dowe, et al. 1957). Such excessive calcium intake was not reflected in the blood plasma. In one trial these workers noticed a significant difference in terminal inorganic phosphorus level of blood plasma between low and high calcium-fed groups. Voelker, et al. (1964) noticed higher consumption of dicalcium phosphate by cows on alfalfa haylage and alfalfa hay than those on corn silage. When haylage was fed mixed with concentrates ad libitum, mineral consumption was lower. There was no significant effect on milk yield, body weight or haylage consumption by high mineral intake.

High dicalcium phosphate intake had little effect on the haylage consumption or body weight gains. Vermont workers (Smith, et al. 1965) noticed increasing depression of digestibility of organic matter with widening calcium to phosphorus ratio. There was an inverse relationship between the levels of inorganic phosphorus in the blood and plasma carotene level. This indicates that low blood phosphorus level decreases the rate of conversion of carotene to vitamin A. They also noticed a tendency of decreasing average blood phosphorus level with increasing calcium content of the ration, while the phosphorus content was held constant. Thus it indicates that the differences between treatments for blood phosphorus were not due to variation in calcium-phosphorus ratio alone but probably due to the level of phosphorus in diet as well. Significant increase in serum phosphorus level occurred with calcium:phosphorus ratio of 2:1 and 1:1 in the feed.

Effect of storage on the energy value of alfalfa

The law of conservation of energy states that energy is not destructible. It is evident that the potential energy contained in the alfalfa plant system must be converted into kinetic energy of heat during the heating process in the bale or hay stack. In this case partial oxidation of the substance might be involved in the evolution of kinetic energy in the form of heat. Hendrix (1947) stated that respiratory heat is released continously from the undried hay which has not been heated to the temperature at which respiratory action is destroyed. Intermittent fan operation increases condensation in the upper layers of hay and promotes more favorable condition for mold formation. In mow drying of hay heat of respiration and bacterial actions supply heat during the usual drying period. Woodward, et al. (1936) stated that storage of hay in chopped and unchopped condition affects the chemical composition and energy content. They noticed that chopped hay is heated more than long hay, and finely chopped hay is more heated than coarsely chopped hay.

Shepherd, et al. (1938) found that excessive moisture in hay brings about conditions favorable for oxidation and excessive heating. Reducing moisture level to a point in the hay before storage prevents excess heating and preserves color and carotene content. In their experiment long first cutting hay with 25% moisture content stored in a mow reached a maximum temperature of 120°F and remained above air temperature for 3 weeks. Coarsely chopped hay with 25% moisture content reached maximum temperature of 128°F in 19 days and did not return to air temperature for 2 months. Watson (1939) stated that most suitable moisture level is from 20-24%; below this level the hay loses color and gets bleached.

When hay with 55 to 65% dry matter was tightly packed in a silo, oxygen was replaced with carbon dioxide in the course of 1 to 3 hours through the respiration of the living plant cells. Thereafter if the air was effectively prevented from entering, there was no heating and spoilage (Samarani, 1922).

Experiments conducted by Wilkinson, et al. (1965) revealed that respiration rate increased with the increase of moisture content or temperature or both in freshly wilted alfalfa. It ranged from zero to 25,000 B.T.U./hour per ton of fresh alfalfa dry matter over 3-5 days period at 80°F. Wilted alfalfa silage had lower respiration rate at the same temperature than fresh alfalfa. Energy loss due to respiration was nil at 25°F or below. Roffler, et al. (1963) estimated the digestible energy value of alfalfa-brome wilted silage, hay and low moisture silage to be 2.91, 3.05 and 2.13 by use of goats. Net energy value of alfalfa hay remains essentially the same when coarsely cut in a silage cutter, as when finely ground in to a meal (Forbes, et al. 1925), but metabolizable energy is slightly higher in hay than meal.

In general estimated net energy value of alfalfa hay averages about 406 therms per 100 pounds. A comparison of different quality alfalfa shows net energy value in fair alfalfa hay, good hay and leafy hay to be 38.2, 40.1 and 43.5 therms respectively for 100 pounds of each variety (Morrison, 1956). Morrison stated net energy value of silages like alfalfa brome (not wilted), alfalfa silage (wilted) and unwilted alfalfa silage to be 14.5, 36.2 and 24.7 therms respectively for 100 lbs. of each moisture level of silage.

According to Joint U. S.-Canadian tables of Feed Composition (1964) the gross energy value of dry cured alfalfa hay is 4500 K cal per kg, whereas brown cured dry alfalfa hay has 4269 K cal per Kg gross energy value. Digestible energy and metabolizable energy is higher in brown alfalfa dry hay than alfalfa wilted-silage or cured brome hay.

Forage quality and ammoniacal nitrogen

Earlier work by Thomas, et al. (1961) has shown reduced intake of silage dry matter, when ammonium compounds were added to the ration of dairy heifers. Ammoniacal nitrogen portion of the total nitrogen was higher in silage and the hot water insoluble portion of total nitrogen was lower in the silage in comparison to the hay (Waldo, et al. 1965). They noticed reduced utilization of nitrogen by dairy heifers from silage ration, possibly due to changes in the form of nitrogen or energy brought about during the silage fermentation processes. Gordon, et al. (1965) detected a higher percentage of ammoniacal nitrogen in their control silage, which was exposed to mold growth undergoing a process of spoilage. The amount of dry matter loss was about twice as high in this type of mold-grown silage as in Mylone-treated good silage.

Whitehead, et al. (1948) stated that a high level of ammonia is toxic to animal tissue. Marked increase in ammonium content occurs when the organic intermediates (keto-acids) for assimilation have been depleted. Increase of ammonia mainly occurs due to the breakdown of proteins and intermediate nitrogen compounds. Increase in soluble nitrogen found in corn leaves (in fall) is associated with decomposition of leaf protein and slight increase in nitrate nitrogen.

Jacobson, et al. (1963) noticed disappearance of nitrate from high moisture grass silage in the early fermentation stage prior to development of low pH, but with low-moisture silage such as haylage, only 19-21% of nitrate disappeared.

Wilting reduced ammonia, titratable acidity and butyric acid production (Zimmer, et al. 1964) from alfalfa silage. There was an increase in dry matter, amino nitrogen, non-protein nitrogen and reducing sugars in the wilted silage (Allen, et al. 1958).

Direct cut silage was higher in ammoniacal nitrogen, lactic acid, butyric acid and propionic acid than hay or haylage. Heifers fed direct cut silage had lower rate of gain, intake and efficiency than those on haylage and hay ration (Thomas, et al. 1961).

Gordon, et al. (1961) noticed high negative correlations between silage dry matter consumption and content of volatile organic acids and ammoniacal nitrogen during their feeding trial.

MATERIALS AND METHODS

The studies herein reported were designed to determine the effects of storing alfalfa hay exposed to weather on its (1) gross energy value, (2) chemical composition, (3) feed intake and growth rates of dairy heifers and (4) on calcium and phosphorus assimilation in comparison to low moisture alfalfa silage and alfalfa hay cured with no rain damage and stored in a barn.

This research was conducted in three phases:

Phase I. Comparison of gross energy value and chemical composition (dry matter, crude protein ether extract, crude fiber and ash) of well protected good hay, unprotected brownish moldy hay and low moisture silage prepared from alfalfa cut at the same time.

Phase II. Chemical analysis of the above noted three types of feed prepared from alfalfa raised from the same fields followed by a feeding trial with dairy heifers.

Phase III. Feeding trial with grain mixture containing sodium phosphate to observe its effect on the weight gains of dairy heifers fed the above-mentioned alfalfa forages as their only ration.

Phase I.

The chemical analysis and gross energy evaluation research started in the last week of January, 1965 with the stored forage from the dairy farm of South Dakota State University. Third cutting immature alfalfa was obtained from six different fields during the last week of September, 1964. The hay was stored as bales in the hayloft of the dairy barn. Detailed information about moisture content of the forage during baling, foreign matter contents, and types of growth was not available.

Moldy hay. Alfalfa hay bales prepared from 3rd cutting alfalfa of Wilson farm was stored in the north shed of the University dairy barn. Most of these bales were browned and full of grayish moldy patches. A type of musty moldlike odor developed in the bales. This was cut during the last week of August, 1964. Other detailed information was not available concerning curing conditions.

Low moisture silage. Low moisture silage was prepared from 4th cutting immature alfalfa forages from the same field. The alfalfa was ensiled in the west concrete stave silo of dairy barn on September 29, 1964.

Sampling methods. Samples from good and moldy alfalfa hay were collected at random from each layer of the hay. Hay bales were opened and samples were collected from the different layers. Low moisture silage samples were collected at three intervals. This was done to get samples from different depths of silage in the silo. The samples were thoroughly mixed and divided into several sub-samples. Polyethylene bags were used to collect the samples. Samples were ovendried at 70°C for 48 hours and ground as soon as possible after collection and were preserved in air tight glass jars for chemical analyses.

Materials for Phase II experiments.

Second cutting alfalfa and brome was used to prepare good hay, moldy hay and low moisture silage. This mixture contained about 10% brome and 90% alfalfa.

Alfalfa was in the early bloom stage and the brome had just begun to head at the time of cutting. The average height of alfalfa plants was 2 feet. Leaf to stem ratio was about 45:55. Stems ranged from medium to fine. The forage contained 1 to 2% foreign material. The alfalfa was cut with an Owatonna swather. After wilting for about 36 hours the alfalfa was chopped for silage. It contained about 41% moisture.

Low moisture silage. One concrete stave silo was filled on July 12, 1965. The forage was chopped with a forage harvestor to a 3/8 inch theoretical length using sharp cutter knives. The silo was filled as rapidly as possible up to three-fourths of its capacity. Samples were taken for chemical analysis and gross energy estimation on every second truck load of chopped alfalfa forage before ensiling. A grab sampling technique was used to obtain representative samples of the loads.

Good hay. Hay bales were field cured and stored in the Central barn, well protected from sun and rain damage. No rain was encountered while the good hay was cured in the field.

Moldy hay. To prepare similar quality of moldy hay as was examined during the Phase I period, artificial methods were followed. All the bales for this purpose were stacked out doors. Water was sprinkled on each layer by a garden sprinkler in amounts of 1.5 to 2 inches of rainfall equivalent so that the entire bale could be soaked with water. Within three days after stacking there was a rise in temperature in these bales. After a week all the bales on the top and sides of the stack bleached in color, but centrally placed bales developed a brownish color. Browning was less apparent in the top layer and side layers of the stack. Grayish white mold developed all over the centrally placed hay bales. A musty penetrative moldy odor developed in all these bales. Some bales on the bottom of the stack became black and putrid. This was done to simulate conditions of storing baled hay out doors which is practiced by some farmers.

Recording of temperature. Temperature recording was started in the silo 12 hours after filling and in the hay 6 hours after stacking. Daily forenoon and afternoon temperatures were recorded by inserting a sensitive dial probe thermometer at a depth of 2 feet below the surface in the center of the concrete stave silo. From the hay stacks temperature was recorded by taking the average of temperatures from the center of the bales located in the middle of each layer of bales. In this way daily temperatures were recorded for 38 days from July 13 to August 20, 1965.

Feeding trial. A feeding trial for Phase II experiment was conducted for 99 days starting from July 2, 1965. Twenty-seven Holstein heifers and 9 Guernsey heifers of the South Dakota State University dairy herd were used for this trial. Body weights of these heifers ranged from 591 to 1083 pounds and ages ranged from about one to nearly two years. A preliminary period of three weeks was used before starting the trial. During this time the heifer rations were gradually changed from corn silage and alfalfa hay to only alfalfa. They were divided into three comparable groups containing 9 Holsteins and 3 Guernseys in each group, based on body-weight. Group I was given only alfalfa low-moisture silage, group II moldy hay, and group III good hay during the experimental period. Each group was supplied with dicalcium phosphate and trace mineral salt free choice, which was weighed into separate wooden boxes.

Body weights were recorded on all the heifers regularly at seven day intervals until the end of the trial. These weights were taken at approximately the same time between feedings each week in order to reduce the changes in relative amounts of fill and to allow greater precision of this measurement. All groups received their prescribed feed twice daily, and at the same time weigh back from the previous feeding was determined.

All three groups of heifers were housed outside in large pens with constant access to water. They were checked every day for injuries, sickness and estrus.

Feed samples. Representative samples of good hay, moldy hay and low-moisture silage were collected daily for the respective groups of heifers from their supply of feed. These samples were brought to the laboratory in air tight polyethylene bags to protect from loss of moisture. From July 23 to August 19, 1965 the same type of samples of two consecutive days were composited to one and from August 20 to September 15 the same type of samples of 3 consecutive days were composited to one sample. This was done to reduce the laboratory work.

These samples were analyzed for the following constituents: dry matter, crude protein, ether extract, crude fiber, ash, hydrogen ion concentration expressed as pH, and ammoniacal nitrogen. Gross energy value for each composite sample was determined by the use of an adiabatic oxygen bomb calorimeter. Calorimetry procedure was followed from Parr Manual No. 120.

Chemical analysis. Dry matter was determined by drying the samples in a Despatch oven at 70°C for 48 hours. Difference between the initial weight and dried weight of the sample gave the estimate of moisture loss. These samples were then ground in a Wiley mill and preserved in air tight glass jars after thorough mixing for further chemical analyses.

Crude protein, ether extract, crude fiber, ash, calcium and phosphorus determinations were made following the Association of Official Agriculture Chemists (A.O.A.C.) methods of analysis. The pH measurements were made with a Beckman pH meter on the feed samples collected during the second phase of the research using 100 ml water and 11 g of forage mixture.

Ammoniacal nitrogen estimation. A.O.A.C. methods of analysis (sec. 2.040) was followed with these modifications: 25 gms of ground forage of each type was taken with 250 ml of hot water separately. The pH of this mixture was adjusted to 5.0 - 6.0 (acidic) by the use of 1% phosphoric acid and 100 ml of the filtrate from each mixture was taken to distill ammonia by Kjeldahl method using magnesium oxide.

Phase III trial.

The feeding trial carried out during the second phase of the research was conducted using the following modifications: free choice supply of dicalcium phosphate to all three heifer groups was discontinued. A concentrate mixture of ground yellow dent corn and wheat bran in 1:1 ratio (by weight) containing 2% sweet phosphorus (sodium phosphate) was supplied to each group at the rate of four pounds per heifer daily. This was fed for three weeks from September 24, 1965 through October 8, 1965. Subsequently the same amount of grain mixture containing 5% sweet phosphorus was fed for another two weeks through October 22, 1965.

Free choice trace mineral mixture was furnished with good hay, moldy hay and low-moisture silage to the respective groups. Body weights were taken regularly every week until the end of this trial.

Two weeks of adjustment period was allowed between the end of the second phase and beginning of the third phase of the trial.

RESULTS AND DISCUSSION

The first phase of this research was conducted with a view to (1) develop methods and techniques of analysis (2) to obtain general information concerning possible differences in the gross energy value and chemical composition of alfalfa under different methods of storage. Therefore the research started with the available forage samples from the dairy barn of South Dakota State University.

Sixty samples from each of good hay, moldy hay and low moisture silage were collected at random and were composited to 20 representative subsamples each. The chemical compositions on dry matter basis are presented in Table I.

Table I. Composition of Phase I feeds

Constituents	Good hay	Moldy hay	Low moisture silage
Dry matter (%)	88.67	84.54	43.65
Ether extract (%)	1.61	1.23	2.72
Crude fiber (%)	26.56	28.96	21.70
Crude protein (%)	21.27	19.72	20.46
Ash (%)	9.0	12.91	11.13
Calories per gm	4.33	3.96	4.23

Good hay contained about twice as much dry matter as low moisture silage. Moldy hay exposed to weather had slightly less dry matter than good hay. Crude protein content of good hay appeared higher and the ash content was lower than the other two types of forages.

Low moisture silage showed the lowest crude fiber content and the highest fat content. Percentage of ash in low moisture silage was higher than in good hay. Moldy hay was very high in crude fiber and ash content. Its ether extract and crude protein contents were lower than the other two types of roughages.

Gross energy value calculated per gram of dry matter was 4.326 in good hay and 4.230 in low moisture silage compared to 3.958 in spoiled hay. This decrease probably is due to the loss of energy during heating and molding process. Stacking of hay without protection to weather conditions causes bleaching of normal green color and favors mold development.

Swanson, et al. (1919) concluded that, wilted alfalfa with more than 50% moisture when stored in a stack becomes brown due to the heat development inside the bales. This causes loss in dry matter, protein and ether extract.

Increase in crude fiber and ash content is probably the indirect effect of loss of nutrients from the total dry matter. Higher percentage of ether extract in low moisture silage is perhaps related to the lactic acid fermentation in the silo and increase in ash percentage can be explained on the basis of decrease in non-ash materials.

Hay prepared with a fairly low moisture content when stored protected from weather conditions appears to retain the maximum nutrients of alfalfa with minimum chemical change.

In order to determine possible differences in feeding value the second phase of this research was conducted with a heifer feeding trial.

Analysis of feed samples collected during Phase II feeding trial

Information gathered from the chemical compositions of forages during first phase of the research included analyses on the feed samples of the feeding trial. Increase in the ash content and decrease in crude protein content of hay due to the exposure to weather conditions and mold growth raised the following questions:

(1) What are the possible ways of protein loss from moldy hay?

(2) What is the value of crude protein contained in moldy hay in comparison to good hay as regards body weight gain in dairy heifers?

(3) What effect does molding process have on the calcium and phosphorus utilization from alfalfa hay?

(4) What can be an approximate measurement of spoilage in alfalfa hay caused by exposure to open weather conditions and mold growth?

This time the samples were collected from the feed mangers of the respective heifer groups to give a true picture of the chemical composition of feeds actually consumed by the heifers. These chemical composition values were compared with the dry matter obtained from the alfalfa plants fresh from the field. Ten representative samples were collected by grab sampling technique from every second truckload of of chopped alfalfa before ensiling. This was done to get a true picture of change in the organic constituents during the storage processes.

In order to determine the calcium and phosphorus consumption of heifers from these types of forages, analyses were made for calcium and phosphorus. Joint U. S. and Canadian Tables of Feed Composition (1964) show a higher calcium content in alfalfa leaves than stems. Alfalfa leaves were selectively consumed by the heifers fed hay, so the stemy weigh back portions of good hay and moldy hay were analysed for calcium and phosphorus content to determine differences in calcium and phosphorus of total hay and refused stems.

Losses. Average bale weights of good and moldy hay were taken during the experimental period. Good hay averaged 54.4 pounds per bale in comparison to 47.6 pounds per bale of moldy hay although the moisture content of moldy hay was slightly higher than that of good hay. This indicates the probability of dry matter loss from hay due to the process of heating and molding. Heat labile organic matter may be lost during the heating process in the bales. In order to know the extent of heating in the experimental forages daily temperatures were recorded in the stack, barn, and silo storage.

Temperature changes. The changes in temperature of three different types of forages are presented in Table II. Moldy hay reached a maximum temperature of 57°C two days after stacking, while good hay did not show any remarkable heating effect. Temperature in good hay was mostly influenced by the atmospheric temperature. During the

Table II. Temperature changes in alfalfa forages in different storage units

Date	Silo				Good hay				Spoiled hay			
July 1965	a.m.	Diff*	p.m.	Diff*	a.m.	Diff*	p.m.	Diff*	a.m.	Diff*	p.m.	Diff*
	(centigrade degrees)											
13	42	20.9	48	22.4								
14	54	36.2	56	30.4			32	6.4			30	4.4
15	58	35.8	60	28.9	31	8.8	31	-0.1	48	25.8	52	20.9
16	57	32.0	62	29.2	31	6.0	33	0.2	48	23.0	51	18.2
17	60	37.8	62	29.8	31	8.8	32	-0.2	57	34.8	47	14.8
18	57	35.3	62	29.8	31	9.3	34	1.8	51	29.3	49	16.8
19	63	43.6	61	38.8	35	15.6	34	11.8	56	36.6	54	31.8
20	64	42.9	59	37.3	33	11.9	28	6.3	48	26.9	49	27.3
21	61	36.0	62	32.0	31	6.5	30	0.0	44	19.0	47	17.0
22	60	33.3	60	24.4	34	7.3	37	1.4	48	21.3	44	8.4
23	61	36.6	61	38.2	36	11.6	34	6.2	43	18.6	45	17.2
24	55	38.3	57	29.8	34	17.3	34	6.8	44	27.3	44	16.8
25	55	36.7	56	26.6	27	8.7	29	-0.4	38	19.7	40	10.6
26	51	32.1	49	24.6	31	12.1	32	7.6	44	25.1	43	18.6
27	50	30.6	50	25.0	32	12.6	32	7.0	43	23.6	43	18.0
28	47	28.1	48	20.2	29	10.1	28	0.2	39	20.1	38	10.2
29	45	26.7	46	14.9	28	9.7	28	-3.1	39	20.7	37	5.9
30	43	21.3	45	22.8	28	6.3	29	6.8	38	16.3	39	16.8
31	47	29.8	46	21.6	29	11.8	26	1.6	38	20.8	37	12.6

*Difference from atmospheric temperature

Table II. Temperature changes in alfalfa forages in different storage units (cont)

Date	Silo				Good hay				Spoiled hay			
August 1965	a.m.	Diff*	p.m.	Diff*	a.m.	Diff*	p.m.	Diff*	a.m.	Diff*	p.m.	Diff*
	(centigrade degrees)											
1	45	21.7	44	18.4	28	4.7	26	0.4	36	12.7	36	10.4
2	46	29.3	50	21.1	26	9.3	28	-0.9	35	18.3	36	7.1
3	47	25.9	48	20.2	27	5.9	28	0.2	35	13.9	41	13.2
4	49	26.2	50	21.1	27	4.2	28	-0.9	39	16.2	40	11.1
5	49	25.7	50	22.2	30	6.7	30	2.2	39	15.7	41	13.2
6	46	23.8	48	21.3	28	5.8	29	2.3	39	16.8	41	14.3
7	49	31.2	50	28.9	28	10.2	28	6.9	41	23.2	42	20.9
8	49	33.5	48	23.0	28	12.5	30	5.0	41	25.5	40	15.0
9	46	27.7	47	18.7	28	9.7	28	-0.3	40	21.7	36	7.7
10	47	24.8	46	14.3	26	3.8	26	-5.7	34	11.8	33	1.3
11	45	21.1	46	14.9	25	1.1	27	-4.1	32	8.1	32	0.9
12	44	19.0	48	10.8	26	1.0	26	-11.2	33	8.0	36	-1.2
13	46	22.1	49	12.3	26	2.1	27	-9.7	34	4.1	37	0.3
14	47	20.3	49	18.4	28	1.3	29	-2.6	38	11.3	36	5.4
15	48	23.0	46	18.2	27	2.0	26	-1.8	33	8.0	32	4.2
16	46	26.6	48	19.7	25	5.6	26	-2.3	33	13.6	35	6.7
17	47	28.7	48	23.0	24	5.7	25	0.00	35	16.7	36	11.0
18	45	29.4	45	18.9	24	8.4	25	-1.1	30	14.4	29	2.9

*Difference from atmospheric temperature first week the average temperature in moldy hay bales remained almost 30°C higher than the atmospheric temperature. Bales on the top and side layers of the stack were not heated as much as the central bales. There was a very slow decline in temperature after the first week. Until the end of the third week the average temperature inside moldy hay bales remained higher than 40°C. Average temperature of good hay was about 30°C and there was not much difference from the normal daily atmospheric temperature.

The temperature in the silo became maximum three days after ensiling. This temperature of 62°C remained the same for the next 3-4 days. During the first week a rapid mold growth developed in the top layers of the low moisture silage. Grayish white flakes of mold spread throughout the layer. On the eighth day morning the temperature became 63.5°C. This increase may be associated with the mold development. Average temperatures remained above 57°C until the end of the second week and then very slowly declined to 47°C by the end of four weeks after ensiling. It has been found that drying of alfalfa herbage at higher temperatures causes loss of total available carbohydrates from the plant (Raguse, et al. 1965). Therefore prolonged heating is probably responsible for lowering the energy value in storage.

Changes in pH. The pH changes for the low moisture silage were recorded ten days after ensiling. By this time the silo unloader was fixed and the top layers of moldy materials were mostly removed. Some flakes of mold still could be seen with the silage and a slightly musty aroma was present. The pH gradually declined from 6.3 to 5.5 within a week. The musty smell was almost gone and a good silage aroma developed. This indicated the influence of mold on the pH. Therefore, recording of pH in good hay and moldy hay was started. After August 10, 1965 good hay showed almost a constant pH of 6.0 throughout.

Moldy hay showed a variable pH from 6.5 to 7.95. As mold developed the moldy hay became more alkaline than good hay. The average pH values for moldy hay, good hay and low moisture silage were 7.05, 6.02 and 5.6 respectively (Table III).

The average of chemical analyses for the dry matter constituents of different types of forages used in Phase II experiments are presented in Table IV.

The statistical analyses of the data are presented in Table V. No statistical analysis was computed on the organic constituents of fresh cut alfalfa samples, because they were not used in heifer feeding trials. Summaries of the chemical analysis for individual composite samples taken from good hay, moldy hay and low moisture silage are given in Appendix tables V, VI, VII and VIII. Analysis of variance was used according to the methods of Steel and Torrie (1960). Duncan's new multiple range test procedure was applied to individual treatment comparisons, which had been found significant by initial analysis of variance. Ether extract, crude protein and ash contents of low moisture silage were significantly higher ($P<.01$) than those

Table III. pH changes of different types of forages

Date	Low moisture silage	Date	Low moisture silage	Good hay	Moldy hay
	(pH)		(pH)	(pH)	(pH)
7/23/65	6.10	8/10/65	5.37	5.90	6.85
7/24/65	6.30	8/11/65	5.58	6.00	6.90
7/25/65	6.20	8/12/65	5.90	6.10	7.25
7/26/65	6.10	8/13/65	5.80	6.10	6.65
7/27/65	6.10	8/14/65	5.90	6.00	6.75
7/28/65	6.30	8/15/65	5.90	6.00	6.90
7/29/65	5.80	8/16/65	5.70	5.95	7.10
7/30/65	5.80	8/17/65	5.50	5.98	7.22
7/31/65	5.70	8/18/65	5.65	6.00	6.78
8/1/65	5.80	8/19/65	5.68	6.12	7.65
8/2/65	5.50	8/20/65	5.56	6.18	7.30
8/3/65	5.80	8/21/65	5.66	6.02	7.00
8/4/65	5.55	8/22/65	5.37	6.01	6.60
8/5/65	5.36	8/23/65	5.40	6.00	6.86
8/6/65	5.63	8/24/65	5.42	6.07	7.05
8/7/65	5.35	8/25/65	5.44	6.00	7.10
8/9/65	5.50	8/26/65	5.58	5.90	7.94
Average pH	5.81		5.61	6.02	7.05

Table IV. Chemical composition of feed samples used in Phase II experiments

Constituents	Fresh cut alfalfa	Good hay	Moldy hay	Low moisture silage
Dry matter (%)		87.91	86.09	52.97
Ether extract (%)	2.07	1.64	1.45	2.55
Crude fiber (%)	25.40	30.29	30.71	27.30
Crude protein (%)	19.36	17.62	17.86	19.22
Ash (%)	10.07	8.79	9.42	10.55
Nitrogen-free extract (%)	43.10	41.60	40.56	40.00
Ammoniacal N (% of protein)		4.42	10.90	7.20
Calcium (%)	1.82	1.54	1.67	1.76
Phosphorus (%)	0.36	0.35	0.36	0.39
Gross energy value (per gm/d.m.)	4.26	4.15	4.11	4.15

Table V. Analysis of variance of chemical constituents of experimental feed samples

	Source of variation				
	Among treatments		Within treatments		
Constituents	Degrees of freedom	Mean square	Degrees of freedom	Mean square	F value
Ether extract	2	7.91	66	0.09	87.89**
Crude fiber	2	79.43	66	6.80	11.68**
Crude protein	2	14.41	66	1.48	9.73**
Ash	2	18.87	66	1.83	10.31**
Ammoniacal nitrogen	2	19.88	57	0.11	180.73**
Calcium	2	0.10	21	0.13	0.74 N.S.
Phosphorus	2	0.01	21	0.02	4.62*
Gross energy	2	0.01	63	0.01	1.80 N.S.

N. S.	Not significant
*	Significant at 5% level of probability
**	Significant at 1% of probability

of moldy hay and good hay. Good hay had higher ether extract value ($P < .01$) than moldy hay, but no significant difference ($P < .05$) could be noticed in crude protein and ash values between moldy hay and good hay.

Moldy hay was higher ($P < .01$) than low moisture silage and good hay in ammoniacal nitrogen. Low moisture silage was also significantly higher ($P < .01$) than good hay. There was no significant difference between the crude fiber content of good hay and moldy hay ($P < .05$), but both were significantly higher ($P < .01$) than low moisture silage. Phosphorus content was not significantly different in all three feeds.

The chemical composition of the feeds presented in Table IV show a great deal of difference between the fresh cut alfalfa and the stored feeds. Ether extract in the fresh cut alfalfa was 2.07% which was reduced to 1.64% and 1.45% in good hay and moldy hay respectively. This indicates the probability of the loss in some volatile oils or heat labile fatty acids from the green alfalfa plant during drying. A further reduction of crude fat might have occurred due to the prolonged heating process in the moldy hay stack.

It is known that complete destruction of carotene leads to the loss in ether extract portion of alfalfa hay (Hoffman, 1937). During the molding and browning processes hay bales were completely bleached. This may be related to the loss of ether extract from moldy hay. Average crude fiber contents of good hay and moldy hays were about the same. Low moisture silage showed remarkably lower crude fiber content than the hay samples. Fresh cut alfalfa showed higher content of crude protein and lower crude fiber than the stored forages. This may be correlated with the leaf loss during wilting and storage. More leafy portion of plants are saved in preparation of low moisture silage than in hay as some leaves are lost in curing hay. Percentage of ash, calcium and phosphorus are seen to be correlated in all the forages. A higher ash content showed a proportionate increase in calcium and phosphorus percentage. They are also presumed to be related to the leaf content of the particular type of forage. Moldy hay shows a relatively higher percent of ash, calcium and phosphorus than that of good hay because organic matter is lost in molding, thus increasing the inorganic content.

While comparing the chemical analysis data of Phase I forages with those of Phase II, moldy hay showed a distinct variation. Crude protein, ether extract and gross energy values were remarkably low in moldy hay analysed during Phase I compared to good hay and low moisture silage. Crude fiber and ash content showed the reverse picture. In this analysis such distinct differences were not noticed. It may be recalled that the forage samples analysed from the dairy barn of South Dakota State University during the first phase were stored for about five months after cutting but during the second phase enough time was not allowed to note the changes due to prolonged exposure to weather conditions and molding of hay. Samples were drawn for chemical analysis after only ten days of stacking the hay outside. Heifer groups on moldy hay started eating from the stack immediately the next day after stacking.

Watson (1939) noticed the total loss of digestible protein in very badly heated hay, and slight heating reduced the apparent digestibility of protein by 50%. This indicates that crude protein portion of moldy hay analysed during the first phase of research gives a more authentic picture of nutrient-loss upon prolonged storage than the second phase analysis.

Gross energy values per gram of dry matter did not vary distinctly among good hay, moldy hay and low moisture silage. This shows that there was only a slight change in gross energy during the short period of storage. It is evident from the first phase analysis that the prolonged effect of mold and weather conditions showed a direct influence on lowering the gross energy value of hay. Ammoniacal nitrogen estimation from moldy hay led to some interesting modifications in the A.O.A.C. procedure. This was determined by Kjeldahl method of distillation of the hot water soluble portion of total nitrogen from the ground feed samples. Good hay and low moisture silage gave an approximate constant result, whereas variable results could be detected from equal amounts of moldy hay samples. Later it was noticed that, increase in pH over 6.0 resulted in the escape of ammoniacal nitrogen from the solution, but in good hay the pH was mostly near 6.0 and low moisture silage had pH ranging from 5 to 6.0. Therefore, the pH of ground moldy hay mixture in hot water was adjusted to 5.5 - 6.0 to serve the following purposes:

(1) To retain the ammoniacal nitrogen portion

(2) To prevent excessive breakdown of amide nitrogen to ammoniacal nitrogen

There was a gradual tendency of increase in the ammoniacal nitrogen portion in moldy hay. This can be correlated with the extent of mold development with lapse of time.

The average ammoniacal nitrogen value was calculated in terms of percentage of total protein in the feed. These values, 4.4, 7.2 and 10.9 percent of total protein of good hay, low moisture silage and moldy hay respectively were estimated to be lost as ammoniacal nitrogen.

Investigators have correlated the ammoniacal nitrogen fraction of forages with the extent of bacterial action and protein decomposition (Gordon, <u>et al</u>. and Wald, <u>et al</u>. 1965).

Subtracting the ammoniacal nitrogen portions from the crude protein contents of the respective feeds resulted in the net values of 16.85, 16.84 and 15.91 percent of crude protein in good hay, low moisture silage and moldy hay respectively. This shows that mold development affects the crude protein quality of the feed.

Heifer trial

The heifer trial involving 36 dairy animals was started July 2, 1965. Three comparable groups were used. Low moisture silage only was fed to group I heifers, moldy hay to group II and good hay to group III.

Filling of the concrete tower silo was completed by the noon of July 12, 1965, and stacking of hay was completed by the afternoon of July 14, 1965. The respective heifer groups were supplied feed from these units immediately after completion of storage. Initial body weights of the experimental groups were recorded after ten days of adjustment period. Dicalcium phosphate (Digesta brand) and trace mineral salt were given free choice to each group throughout the pre-experimental period. Digestive disturbances were noticed in all groups during the first two weeks, but more heifers fed low moisture silage were affected than in the other groups. They took comparatively more dicalcium phosphate during the first ten days than the other two groups. They looked emaciated and developed rough hair coats. Much of the time they were seen licking the bark of the trees, in their paddock. The other two groups did not show such acute symptoms. Investigations have already referred to the above noted symptoms as "pica", as a result of phosphorus deficiency (Riddell, *et al*. 1934 and Kleiber, *et al*. 1936).

For the first ten days the low moisture silage was moldy. After installation of the silage unloader these moldy materials could be taken out within a week. Low moisture silage obtained below 1½ - 2 feet from the surface was quite good without any further mold growth.

After well-preserved low moisture silage was fed, group I heifers did not show such symptoms. Their hair coats changed to normal and dry matter consumption increased gradually. They looked contented and did not lick the tree trunks. Consumption of dicalcium phosphate also was reduced. This group of heifers consumed some soil, and may have received some of their mineral needs from the soil. Afterwards they looked better than the other two groups until the end of the feeding trial.

These observations indicate that acute phosphorus deficiency could be due to the feeding of moldy silage. From the chemical analysis low moisture silage showed slightly higher amounts of calcium and phosphorus than good or poor hay, but the Ca:P ratio is approximately the same as in the later two feeds. This indicates that mold growth is probably responsible for poorer utilization of phosphorus, which causes an artificial phosphorus deficiency where there is such a high amount of calcium relative to phosphorus.

The second group of heifers fed moldy hay developed symptoms of pica after about two weeks of feeding moldy hay. They had rough hair coats and started chewing the wooden fences. In comparison to the other two groups they looked discontented. They appeared to crave good hay which they would try to steal when they were weighed. They took comparatively more dicalcium phosphate free choice than other groups during the experimental period. This also indicates the effect of mold on calcium-phosphorus assimilation. Most of the time, more than half of the heifers from this group were lachrymating from their eyes whereas one or two heifers from group I and no heifers from group III could be seen lachrymating. This may have been from the lack of vitamin A from moldy hay. Green color of good hay suggested higher carotene content and the heifers in this group did not show this symptom. The heifers on moldy hay perhaps did not receive enough vitamin A because the major portion of their feed consisted of bleached, brownish-moldy hay. Vermont workers have demonstrated a positive correlation between the blood phosphorus and plasma vitamin-A levels in dairy cows (Smith, et al. 1965). The plasma vitamin A level is more likely to be lowered due to the lower phosphorus assimilation from moldy hay.

The third group of heifers fed high quality hay did not show any noticeable deficiency symptoms during the experimental period. During the preliminary adjustment period some heifers showed digestive disturbance, but in two heifers diarrheic conditions lasted comparatively longer than in the other two groups. Dicalcium phosphate intake was high during the preliminary period, and therefore it was temporarily discontinued, being replaced by sodium phosphate. The diarrheic conditions subsided. The heifers did not consume very much sodium phosphate, suggesting that the high dicalcium phosphate consumption was related to the laxation. During the major portion of the trial, excessive laxation was not a problem.

Body weight gains. The average initial and final weights per heifer of each group are given in Table VI. Group I and III heifers showed relatively better body weight gain than group II heifers. Analysis of variance of heifer gains showed that the moldy hay group gained significantly less than the other two groups ($P < .05$). The final weighing of Phase II feeding trial was scheduled to be taken ten weeks after initial weighing. During the last two weeks continuous rain and cold weather caused much stress within the experimental groups. Heifers could not eat properly and lost weight. Therefore the average body weights at the end of eight weeks was taken as final for Phase II feeding trial.

Table VI. Body weight gains of heifer groups

Heifer groups	Feed	No. of days	Average initial weight	Average final weight	Gain	Average daily gain /heifer
			(lb)			
I	Low moisture silage	56	858	966	108	1.93
II	Moldy hay	56	863	945	82	1.46
III	Good hay	56	843	951	108	1.93

In order to show a better picture on the weekly performance of different feeds with respect to body weight gain, average cumulative weight difference was calculated per 100 pounds body weight of heifers per week.

Figure 1 shows the tendency of weekly body weight gains in which heifers on low moisture silage (Group I) show a more linear trend of growth than the other two groups. Group II (moldy hay) had a comparatively more negative trend of weight gain than those in Group III (good hay) during the first three weeks. This may be correlated to their low dry matter intake from wet and heated bales of hay which were becoming molded.

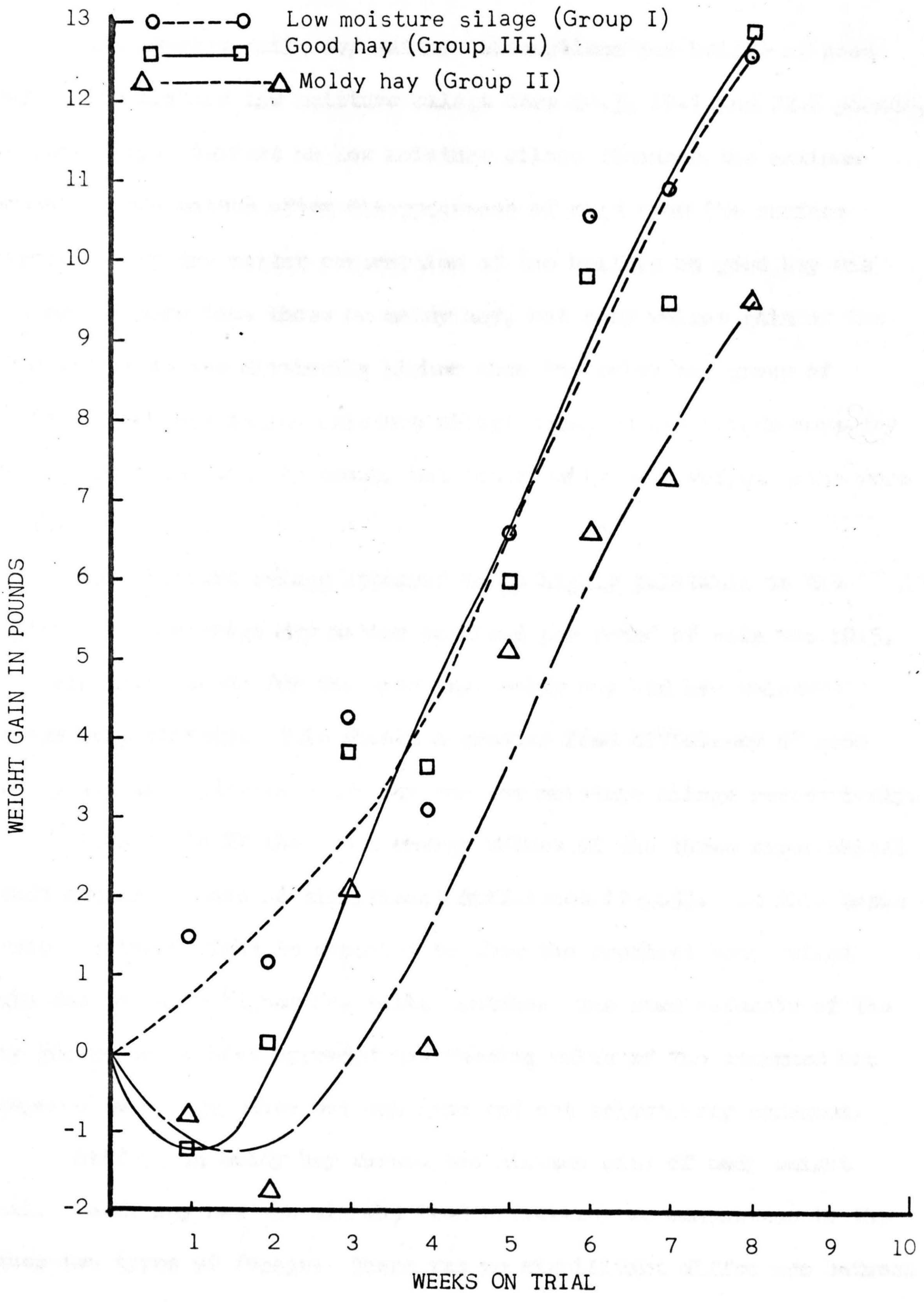

Figure 1. Av. cumulative wt. gains for 100 lb. heifer wt. (Phase II)

The average daily dry matter consumptions per heifer of good hay, moldy hay and low moisture silage were 20.3, 19.1 and 22.8 pounds, respectively. Heifers on low moisture silage consumed the maximum amount of dry matter after disappearance of mold from the surface layer. Daily dry matter consumption of the heifers on good hay was 1.2 pounds more than those on moldy hay, but body weight gain of the good hay group was distinctly higher than the moldy hay group of heifers. Heifers on low moisture silage consumed 2.5 pounds more dry matter than the good hay group, but their daily body weight gains were equal.

Low moisture silage appeared to be highly palatable to the heifers. The average dry matter consumed per pound of gain was 10.5, 13.1 and 11.8 pounds for the good hay, moldy hay and low moisture silage respectively. This showed a greater feed efficiency of good hay by 24% and 12% than moldy hay and low moisture silage respectively.

From Table IV the gross energy values of the three experimental feeds appear to have no significant difference ($P < .05$). On this basis group I heifers might be expected to show the greatest body weight gain due to their higher dry matter intake. The stem refusals of the hay groups could have upgraded the feeding value of the consumed hay compared to silage which was cut fine and not selectively consumed.

Heifers on moldy hay showed the minimum rate of body weight gain. Moldy hay had the minimum feed efficiency in comparison to the other two types of forage. There was no significant difference between the dry matter, crude protein and gross energy value of good hay and moldy hay, but the feed efficiency of good hay exceeded the later by 24%. This is probably due partly to the detrimental effect of browning and molding in the hay bales. During the process of browning the hay bales were heated to 57°C. This temperature declined very slowly to 40°C in three weeks. Such a prolonged heating effect could deteriorate the protein value of the hay. Intense mold development converted 10.9% of the total protein of hay to ammoniacal nitrogen.

The effect of mold development on phosphorus intake of the heifers was noticed during the first two weeks of moldy silage feeding. Thus it is quite evident that heifers on moldy hay could have the maximum trouble for phosphorus assimilation from their feed. All these facts contribute to the low body weight gains from the moldy hay. In the Phase I the ash content of moldy hay was 12.91%, whereas low moisture silage and good hay showed 11.13 and 9% of ash respectively, but second phase analysis showed a higher ash content on low moisture silage than the other two forages. Moldy hay had more ash than good hay. It is presumed from these comparisons that the extent of heating might have a direct interrelation with ash content of the forage. Destruction of organic matter raises the ash proportionately. However, it should be emphasized that feeding moldy hay immediately after stacking reduces any deterioration of feed value due to molding and browning.

Phase III trial

This part of the experiment was designed to determine the effect of higher phosphorus supplement with high phosphorus concentrates on the body weight gains and forage consumption of heifer groups fed alfalfa low moisture silage, good and moldy alfalfa hay rations. Though there was no significant difference between the calcium and phosphorus contents of these experimental feeds, the heifers on hay groups might ingest less phosphorus relative to calcium due to their selective consumption of leafy materials from hay. Weigh-back stems from good hay and moldy hay feed mangers were analysed for calcium and phosphorus. Moldy hay portion showed 0.87% calcium and 0.30% phosphorus, whereas calcium and phosphorus content of weigh-back portions from good hay were 0.79% and 0.23% respectively. Table VII shows the amount of average calcium and phosphorus intake from different type of forages during the entire experimental period. There was no need to analyze the weigh-back of low moisture silage for calcium and phosphorus, because the leaf and stem portions were uniformly mixed and finely chopped in the silage and the heifers had no choice of selective intake of leafy materials. A relatively wider calcium to phosphorus ratio was found from the dry matter intake of moldy hay than the other two forages. Twelve heifers on moldy hay consumed 250 pounds of dicalcium phosphate and 10 pounds of sodium phosphate, free choice, during the Phase II trial; whereas the 12 heifers on good hay consumed 240 pounds dicalcium phosphate and 20 pounds of sodium phosphate. Low moisture silage fed heifers consumed 83 pounds of

Table VII. Average daily calcium and phosphorus intake from experimental feeds

Feed	Average daily dry matter supply	Weigh back	Net consumption of dry matter	Amount of calcium intake	Amount of phosphorus intake	Resulting Ca:P ratio
	(lbs)					
Good hay	309.2[a]	49.9	259.3	4.38	0.98	4.5:1
Moldy hay	298.2[a]	51.6	246.6	4.54	0.92	5:1
Low moisture silage	279.4[a]		279.4	4.93	1.10	4.5:1

[a] Fed to 12 heifers

dicalcium phosphate and 10 pounds of sodium phosphate. This suggests that calcium and phosphorus can be better assimilated from good quality low moisture alfalfa silage, but this effect could not be detected from alfalfa hay.

Progressive symptoms of pica noticed in the heifers in the moldy hay group also suggests the probability of lack of assimilation of phosphorus instead of higher free choice phosphorus intake.

Free choice feeding of dicalcium phosphate causes both calcium and phosphorus intake to be increased. "Sweet phosphorus" (sodium phosphate) supplement was in the grain ration, as it contains no calcium, thus increasing the amount of phosphorus, but not calcium. A mixture was made of half corn and half wheat bran to aid in higher phosphorus relative to calcium intake. Calcium and phosphorus compositions of individual mineral supplements and grains are given in table IX in the Appendix. The 2% sodium phosphate supplement in the corn and wheat bran mixture was followed by increasing it to 5% after 3 weeks. This was done to observe the influence of narrowing the calcium:phosphorus ratio on body weight gains of the experimental heifer groups. A detailed daily calcium:phosphorus intake by individual heifer groups is given in table VIII, when they were fed with different levels of phosphorus supplements during both phases of the feeding trial.

When the grain mixture was fed with 2% sodium phosphate supplement, the total amount of phosphorus intake increased in all groups resulting in 3:1, 3:1 and 2.8:1 calcium:phosphorus ratio in low moisture

Table VIII

Average daily calcium and phosphorus consumption during different phases of the heifer feeding trial

	Groups of heifers		
Rations	I Low moisture silage	II Moldy hay	III Good hay
Feeding trial with voluntary intake of minerals:			
From dry matter of feeds:			
Calcium (gms)	186.41	162.91	159.01
Phosphorus (gms)	41.50	33.21	35.43
From mineral supplements:			
Calcium (gms)	10.95	33.00	31.68
Phosphorus (gms)	10.71	29.25	28.14
Total intake from dry matter and minerals:			
Calcium (gms)	197.36	195.91	190.96
Phosphorus (gms)	52.21	62.46	63.57
Ca:P ratio	3.78:1	3.1:1	3:1
2% Sweet Phosphorus supplementation through the grain mixture:			
From grain mixture:			
Calcium (gms)	1.52	1.52	1.52
Phosphorus (gms)	22.00	22.00	22.00
Total intake from feed and grain mixture:			
Calcium (gms)	187.93	164.43	160.53
Phosphorus (gms)	63.50	55.21	57.43
Ca:P ratio	2.96:1	3:1	2.8:1

Table VIII (cont)

Average daily calcium and phosphorus consumption during different phases of the heifer feeding trial

Rations	Group of heifers I Low moisture silage	 II Moldy hay	 III Good hay
5% Sweet Phosphorus supplementation through the grain mixture:			
From grain mixture:			
Calcium (gms)	1.43	1.43	1.43
Phosphorus (gms)	35.11	35.11	35.11
Total intake from feed and grain mixture:			
Calcium (gms)	187.84	164.34	160.44
Phosphorus (gms)	76.61	68.32	70.54
Ca:P ratio	2.5:1	2.4:1	2.3:1

silage, moldy hay and good hay fed groups, respectively. These respective ratios were further narrowed after two weeks to 2.5:1, 2.4:1 and 2.3:1 when the grain mixture containing 5% sodium phosphate was fed. The body weight gain trends are presented in Figure 2.

It is interesting to note that the heifers on low moisture silage showed an increase in body weight gain with increased amounts of phosphorus and energy. In the other two heifer groups the tendency of weight gain was depressed, as the calcium:phosphorus ratio was narrowed to 3:1 with supplementation of 2% sodium phosphate mixture. This can be better revealed by comparison of the trends of growth from Figure 1 and Figure 2.

Smith, et al. (1965) could not detect any difference in terms of level and persistency of milk production between groups of dairy cows, which were kept on rations with 1:1, 4:1 and 8:1 calcium to phosphorus ratios. Thus no positive remark should be made about the effect of change in calcium to phosphorus ratio on the growth rate of different heifer groups in this experiment.

Anderson, et al. (1965) stated that excessive calcium can reduce the absorption of phosphorus from the diet. According to National Research Council (N.R.C.) recommendations, dairy heifers of 1000 lbs. body weight require 12 grams of calcium and 12 grams of phosphorus daily for normal growth. Visek, et al. (1953) recommended an average daily supply of 8 grams of calcium for 1000 lbs. heavy cow as maintenance requirement. Therefore, it was suggested that calcium content

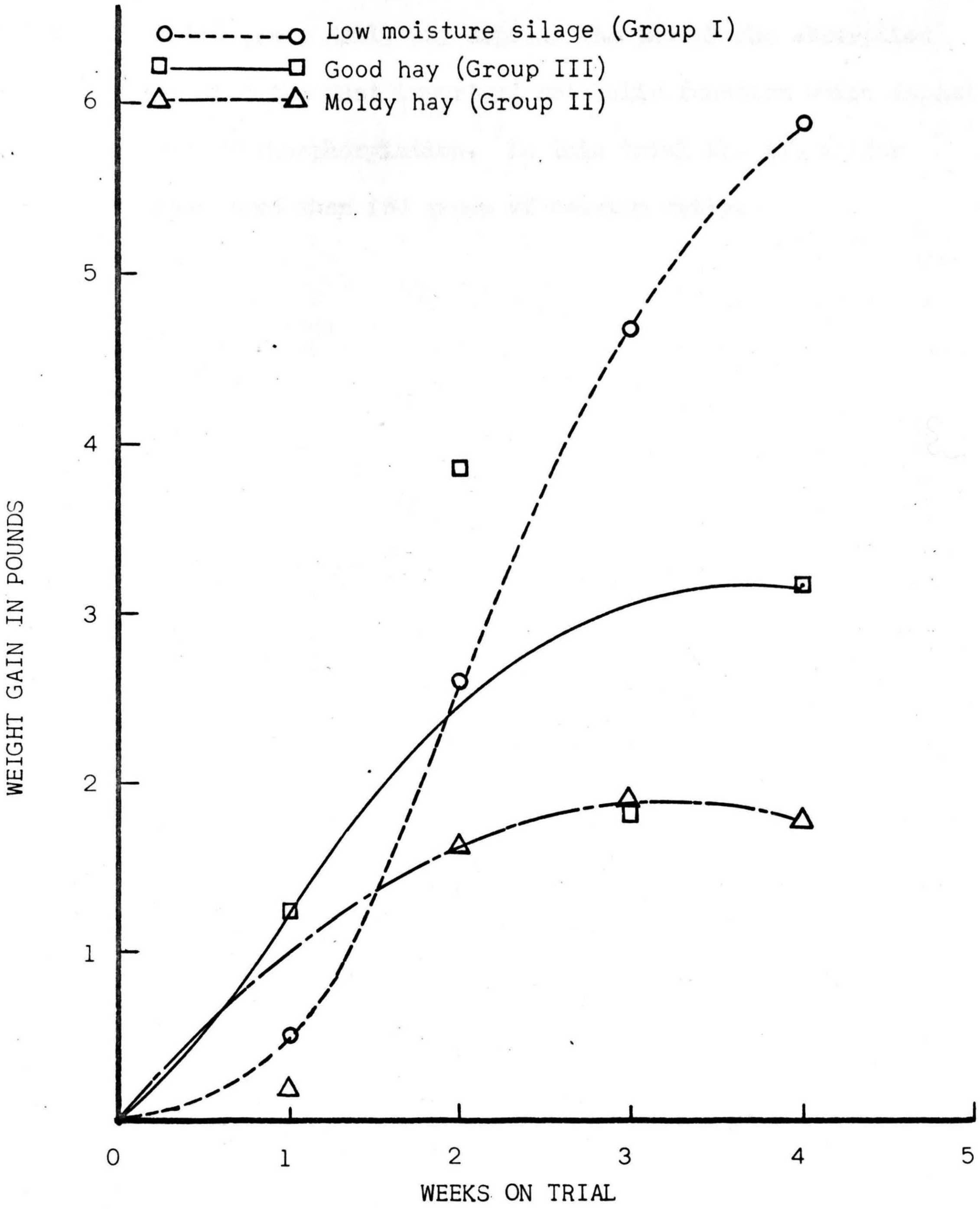

Figure 2. Av. cumulative wt. gains per 100 lbs. heifer wt. (Phase III) (1st 2 wks, 2% phosphorus supplement, last 2 wks 5% phosphorus supplement)

of more than 160 grams daily may depress the phosphorus absorption and interfere with the most important metabolic function which depend on the process of phosphorylation. In this trial all the heifer groups consumed more than 160 grams of calcium daily.

SUMMARY

Alfalfa hay, low moisture silage and browned moldy alfalfa hay were analyzed for gross energy value and chemical composition. Ether extract, crude protein and gross energy values of browned moldy alfalfa hay were comparatively lower, whereas crude fiber and ash contents were higher than in the other two types of roughages.

Daily feed samples were collected for chemical analysis during a heifer feeding trial. The moldy hay showed lower ether extract value than the other two forages, but crude protein, crude fiber and ash values did not differ significantly from good hay. Low moisture silage was lower in crude fiber, and higher in crude protein, ether extract and ash contents than both types of hay. No difference in gross energy value was found between the three kinds of forages. Average pH values of good hay, moldy hay and low moisture silage were 6.0, 7.0 and 5.6 respectively. Ammoniacal nitrogen estimation revealed an interesting correlation between the extent of molding and a proportinate loss of nitrogenous matter from forages with the increase in pH.

To determine the effect of molding on the nutritional values of alfalfa hay the heifer feeding trial was conducted with good alfalfa hay, low moisture silage and moldy hay from the same fields. Moldy hay was prepared by sprinkling water over the bales and stacking them exposed to weather. Alfalfa low moisture silage was preserved in a concrete stave silo and well cured hay stored inside the barn,

protected from weather conditions. Temperatures were the highest in the low moisture silage during the first week of fermentation. The water-sprinkled hay temperatures were higher than for well-cured hay.

Twenty-seven Holstein and 9 Guernsey heifers were divided into three groups. Low moisture silage, moldy hay and good hay were fed to the first, second and third group, respectively. The feeding trial was conducted in two phases. Dicalcium phosphate and trace mineral salt were supplied free choice to all groups during the first phase. A phosphorus supplement mixed with grain was supplied in place of free choice dicalcium phosphate feeding during the last phase of the trial.

Dry matter consumption was highest from low moisture silage and lowest from moldy hay. Heifers on low moisture silage developed acute phosphorus deficiency symptoms when fed badly molded silage from the surface layer. The deficiency symptoms disappeared shortly after feeding good quality silage from deeper layers. Heifers on moldy hay ration showed deficiency symptoms of phosphorus for a comparatively longer time. The heifers fed good hay were more normal throughout the experiment. The average daily gain for heifers on good hay and low moisture silage was 1.93 lbs each, and 1.46 lbs for those on moldy hay. Daily feeding of four pounds of grain mixture with sodium phosphate showed an increase in weight gains for heifers on low moisture silage, but not in hay-fed heifer groups. The moldy-hay group of heifers had the lowest body weight gains, even with supplemental feeding of high phosphorus grains and sodium phosphate.

CONCLUSIONS

The following conclusions were drawn from the results obtained in these experiments:

(1) Stacking of alfalfa hay outdoors exposed to the weather conditions diminished its feeding value.

(2) Water sprinkling over the hay bales increased browning due to heat development inside the stack. This also favored excessive mold development in the aerated portion of the bales.

(3) Heating had a negative correlation with the ether extract, and a positive correlation with the ash content of the forage.

(4) Ether extract, protein, and ash contents of low moisture silage were significantly higher than those of moldy hay and good hay. Silage was significantly lower in fiber than hay.

(5) Increase in mold growth caused a highly significant breakdown of forage protein to ammoniacal nitrogen, and increased the alkalinity.

(6) A direct relationship was noticed between the alkalinity and loss of ammoniacal nitrogen from moldy hay.

(7) Consumption of moldy alfalfa hay or moldy low moisture silage resulted in depraved appetites.

(8) The feeding of alfalfa hay as the only feed resulted in high intakes of dicalcium phosphate offered free choice.

(9) Gross energy value of moldy alfalfa hay was about equal to that of good alfalfa hay and alfalfa low moisture silage though their feeding values were different.

(10) Good alfalfa hay and low moisture silage had better feed value than moldy hay.

(11) High intake of dicalcium phosphate increased laxation in dairy heifers.

LITERATURE CITED

1. Allen, R. S., and Porter, A. R. 1954. Effect of added ground corn on the composition and palatability of stacked legume-grass silage. J. Dairy Sci., 37:658.

2. Allen, R. S., and Foreman, C. F. 1958. Effect of wilting on preservatives on composition of legume grass silage in miniature silos. J. Dairy Sci., 41:734.

3. Anderson, P. C., and Rapp, J. L. C. 1965. Bentonite and the FSE catalyx mineral program. Feed Service Communique Vol 7(1).

4. Association of Official Agricultural Chemists. 1960. Official methods of analysis. 9th Edition.

5. Axelsson, J. 1938. The preservation of fodder by the addition of acids. J. Dairy Sci., 21:295.

6. Baker, R. J., and Voelker, H. H. 1958. Preservatives for alfalfa silage. J. Dairy Sci., 41:734.

7. Bechtel, H. E., Shaw, A. O., and Atkeson, F. W. 1945. Brown alfalfa hay, its chemical composition and nutritive value in dairy rations. J. Dairy Sci., 28:35.

8. Byers, J. H. 1963. Studies with low moisture silage. J. Dairy Sci., 46:632.

9. Byers, J. H. 1965. Comparison of feeding value of alfalfa hay, silage and low moisture silage. J. Dairy Sci., 48:206.

10. Cannon, C. Y., Collins, E. V., and Espe, D. L. 1937. Comparative efficiencies of hay storing methods. Agr. Engin., 18:153.

11. Colovos, N. F., Keener, H. A., and Davis, H. A. 1955. The effects of pulverized limestone and dicalcium phosphate on the nutritive value of Dairy Cattle feed. J. Dairy Sci., 38:627.

12. Colovos, N. F., Keener, H. A., and Davis, H. A. 1958. The effect of pulverized limestone and dicalcium phosphate on the nutritive value of dairy cattle feed. J. Dairy Sci., 41:676.

13. Dodd, F. R. 1933. Notes on the spontaneous combusion or ignition of hay. Analyst., 58:77.

14. Dowe, T. W., Matsushima, J., and Arthaud, V. H. 1957. The effects of adequate and excessive calcium when fed with adequate phosphorus in growing rations for beef calves. J. Animal Sci., 16:811.

15. Forbes, E. B., Fries, J. A., and Braman, W. W. 1925. Net energy value of alfalfa hay and alfalfa meal. J. Agr. Res., 31:987.

16. Fred, E. B., and Peterson, W. H. 1924. Ensiling partially dried alfalfa. Wis. Agr. Expt. Sta. Bull. 362.

17. Gordon C. H., Shepherd, J. B., Wiseman, H. G., and Melin, C. G. 1951. A comparison of alfalfa hay and slightly wilted alfalfa stored in gas tight steel silos. J. Dairy Sci., 34:493.

18. Gordon, C. H., Melin, C. G., Jacobson, W. C., Wiseman, H. G., Kane, E. A., and Derbyshire, J. C. 1958. Nutrient losses and feeding values of wilted and direct cut forages stored in bunkers and tower silos. J. Dairy Sci., 41:735.

19. Gordon, C. H., Derbyshire, J. C., Wiseman, H. G., Kane, E. A., and Melin, C. G. 1961. Preservation and feeding value of alfalfa stored as hay, haylage and direct cut silage. J. Dairy Sci., 44:1299.

20. Gordon, C. H., Derbyshire, J. C., and Humprey, J. L. 1965. Inhibition of aerobic spoilage in low moisture silage. Paper.. 60th Annual meeting of Am. Dairy Sci. Assn.

21. Guilbert, H. R., Mead, S. W., and Jackson, H. C. 1931. The effect of leaching on the nutritive value of forage plants. Hilgardia., 6:13.

22. Haag, J. R., Jones, I. R., and Brandt, P. M. 1932. The physiological effects of rations restricted principally or solely to the alfalfa plant. III. The influence of various mineral supplements on the calcium, phosphorus and nitrogen metabolism of dairy cattle. J. Dairy Sci., 15:23.

23. Hendrix, A. T. 1947. Heat generated in chopped hay and its relation to drying effect. Agr. Engin., 28:286.

24. Henson, E. R. 1939. Curing and storage of alfalfa hay. Iowa Agr. Expt. Sta. Res. Bul. 251.

25. Hoffman, E. J., and Bradshaw, M. A. 1937. Losses of organic substances in the spontaneous heating of alfalfa hay. J. Agr. Res. 54:159.

26. Jacobson, W. C., and Wiseman, H. G. 1963. Nitrate disappearance in silage. J. Dairy Sci., 46:617.

27. Kleiber, M., Goss, H., and Guilbert, H. R. 1936. Phosphorus deficiency metabolism and food utilization in beef heifers. J. Nutrition., 12:121.

28. Lamb, L. W., Winter, O. B., Duncan, C. W., Robinson, C. S., and Huffman, C. F. 1934. A study of the phosphorus requirement of dairy cattle. II. Phosphorus, Calcium and Nitrogen metabolism of dairy cattle when alfalfa furnishes the principal source of protein. J. Dairy Sci., 17:233.

29. Larsen, H. J., and Johannes, R. F. 1961. Effect on milk production, body weight, and dry matter consumption when feeding haylage, hay and silage with simple concentrate supplements (Abstract) J. Dairy Sci., 44:1175.

30. Lewis, J. K., Burkitt, Wm. H., and Wilson, F. S. 1951. The effect of excess calcium with borderline and deficient phosphorus in the rations of steer calves. J. Animal Sci., 10:1053.

31. Maynard, E. H., Esplin, A. C., and Boswell, S. R. 1932. Lamb feeding experiment in Utah. Utah Agr. Expt. Stn. Bul. 238.

32. McCampbell, C. W. 1919. Cattle feeding investigations. Kans. Agr. Expt. Stn. Director's report., 28-29:1916.

33. Monroe, C. F., Hilton, J. H., Hodgson, R. E., King, W. A., and Krauss, W. E. 1946. The loss of nutrients in hay and meadow crop silage during storage. J. Dairy Sci., 29:239.

34. Moore, L. A., Thomas, J. W., Jacobson, W. C., Melin, C. G., and Shepherd, J. B. 1948. Comparative antirachitic value of field cured hay, barn dried hay, and wilted grass silage for growing dairy calves. J. Dairy Sci., 31:489.

35. Morrison, F. B. 1956. Feeds and Feeding. Edition 22.

36. National Academy of Sciences - National Research Council. 1964. Joint U. S.-Canadian tables of feed composition. Publ. 1232.

37. National Academy of Sciences - National Research Council. 1962. Nutrient requirements of dairy cattle. Publ. 464 (III).

38. Nevens, W. B., and Kuhlman, A. F. 1936. Alfalfa silage. J. Dairy Sci., 19:611.

39. Niedermeier, R. P., and Baumgardt, B. R. 1963. Evaluation of alfalfa-brome forage stored as wilted silage, low moisture silage and hay. J. Dairy Sci., 46:632.

40. Ragase, C. A., and Smith, D. 1965. Carbohydrate content in alfalfa herbage as influenced by methods of drying. J. Agr. Food Chem., 13:306.

41. Riddell, W. H., Hughes, J. S., and Fitch, J. B. 1934. The relation of phosphorus deficiency to the utilization of feed in dairy cattle. Kansas Agr. Expt. Sta. Tech. Bul. 36:

42. Roffler, R. E., Niedermeier, R. P., and Baumgardt, B. R. 1963. Evaluation of alfalfa-brome forage stored as wilted silage, low-moisture silage and hay. J. Dairy Sci., 46:632.

43. Rogers, C. F., and Bell, D. S. 1953. Acceptability of high-dry matter silages. Ohio Agr. Expt. Sta. Res. Circ. 20.

44. Sarmani, F. 1922. The Italian method of ensiling hay. Hoard's Dairy Man., 63:806.

45. Scurti, F., and Mossi, N. 1942. Effect of moisture on feeding stuffs during hay-making. Annuar. Ist. Sper. Chim. Agrar. Torino., 15A:183.

46. Shepherd, J. B., and Woodward, T. E. 1938. Further investigation in chopping alfalfa hay at the time of storage. J. Dairy Sci., 21:89.

47. Shepherd, J. B., Hodgson, R. E., and Sweetman, W. J. 1946. The comparative feeding value of wilted alfalfa silage and alfalfa hay for dairy cows. J. Dairy Sci., 29:551.

48. Shepherd, J. B., Schoenleber, L. G., Wiseman, H. G., Melin, C. G., Sweetman, W. J., Hosterman, W. H., and Tysdal, H. M. 1948. Conservation of nutrients and feeding value of wilted silages; barn cured hay and poor quality field cured hay. J. Dairy Sci., 31:688.

49. Shepherd, J. B., Gordon, C. H., Wiseman, H. G., Melin, C. G., Campbell, L. E., and Roame, G. D. 1953. Comparison of silages stored in gas-tight silos and in conventional silos. J. Dairy Sci., 36:1190.

50. Shepherd, J. B., Wiseman, H. G., Ely, R. E., Melin, C. G., Sweetman, W. F., Gordon, C. H., Skoenleber, L. G., Wagner, R. E., Campbell, L. E. and Roane, G. D. 1954. Experiments in harvesting and preserving alfalfa for dairy cattle feed. U.S.D.A. Tech. Bul., 1079.

51. Smith, A. M., Holck, G. L., and Spafford, H. B. 1965. Re-evaluation of nutrient allowances for high-producing cows: Calcium, phosphorus, and vitamin D. Vermont Agr. Expt. Stn.

52. Spoehr, H. A. 1926. Photosynthesis. The chemical catalog Co. Inc. New York. 393.

53. Steel, R. G. D., and Torrie, J. H. 1960. Principles and Procedures of Statistics. McGraw-Hill Book Company, Inc., New York.

54. Swanson, C. O., Call, L. E., and Salmon, S. C. 1919. Losses of organic matter in making brown and black alfalfa. J. Agr. Res, 18:299.

55. Swift, R. W., Cowan, R. L., Barron, G. P., Maddy, K. H., and Grose, E. C. 1951. The effect of alfalfa ash upon roughage digestion in sheep. J. Anim. Sci., 10:434.

56. Sykes, J. F., Moore, L. A., and Converse, H. T. 1955. Comparison of alfalfa hay and wilted alfalfa silage as a roughage for growing dairy heifers. J. Dairy Sci., 38:613.

57. Thomas, J. W., Moore, L. A., and Sykes, J. F. 1961. Further comparison of alfalfa hay and alfalfa silage for growing dairy heifers. J. Dairy Sci., 44:862.

58. Thomas, J. W., Moore, L. A., Okamoto, M., and Sykes, J. F. 1961. A study of factors affecting rate of intake of heifers fed silage. J. Dairy Sci., 44:471.

59. Visek, W. J., Monroe, R. A., Swanson, E. W., and Comar, C. L. 1953. Determination of endogenous fecal calcium in cattle by a simple isotope dilution method. J. Nutrition., 50:23.

60. Voelker, H. H., and Becker, E. R. 1956. Effect of sodium metabsulfite and iodized sodium chloride on preservation and milk production value of alfalfa silage with levels of protein supplementation. J. Dairy Sci., 39:939.

61. Voelker, H. H. 1959. Preservation losses in bunker, concrete stave and in grass lined silos. J. Dairy Sci., 42:929.

62. Voelker, H. H. 1963. Alfalfa haylage as a feed for dairy cattle. S. Dak. Agr. Expt. Sta. Mimeo. i-37.

63. Voelker, H. H., and Bartle, E. 1964. Effects of types of storage on the feeding values of alfalfa haylage for dairy cattle. S. Dak. Agr. Expt. Sta. Mimeo. HHV-30-31.

64. Voelker, H. H., Cooper, S., and Singh, J. 1964. Supplementation of alfalfa haylage with calcium and sodium phosphate. Paper. 59th Annual Meeting of Am. Dairy Sci. Assn.

65. Waldo, D. R., Miller, R. W., Okamoto, M., and Moore, L. A. 1965. Ruminant utilization of silage in relation to hay pellets and hay plus grain. I. Composition, digestion, nitrogen balance, intake and growth. J. Dairy Sci., 48:910.

66. Watson, S. J. 1939. The Science and Practice of Conservation: Grass and forage crops. The Fertilizer and Feeding Stuffs, 16 Mark Lane, E.C. 3, London.

67. Whitehead, E. I., Viets, F. G., and Moxon, A. L. 1948. Nitrogen distribution in the corn plant. S. Dak. Agr. Expt. Stn. Bul. No. 7.

68. Wilkinson, R., and Hall, C. W. 1965. Respiration rate of harvested forage. Mich. State Univ. Quart. Bul., 47:518.

69. Willard, H. W. 1933. Factors influencing the palatability of hay. Wyo. Agr. Expt. Sta. Bul., 199.

70. Woodward, T. E., and Shepherd, J. B. 1936. An experiment in chopping alfalfa hay at the time of storage. J. Dairy Sci., 19:697.

71. Zimmer, E., and Gordon, C. H. 1964. Effect of wilting, grinding and aerating on losses and quality in alfalfa silage. J. Dairy Sci., 47:652.

APPENDIX

APPENDIX TABLE I

Weather summary during the feeding trial period

Period Week ending	Temperature during the week Lowest	Highest	Average	Weekly total precipitation	Weather
	(degrees F)			(in)	
7/7/65	51	85	67	0.23	Thundershowers mostly during first half of the week.
7/13/65	44	84	67	0.61	Thundershowers scattered throughout the week with greatest amount at the first of the week.
7/19/65	48	91	71	0.00	Clear and dry.
7/26/65	51	94	74	0.00	Clear and dry.
8/2/65	46	88	68	0.05	Partly cloudy.
8/9/65	47	86	70	0.65	Showers scattered throughout the week. Most amounts near end of week.
8/16/65	51	100	75	0.00	Clear and dry.
8/23/65	43	83	65	0.35	Hot and dry during the first half of the week and rainy over the week end.
8/30/65	33	87	62	0.20	Thunder showers scattered throughout the week.

Appendix Table I (cont)

Period Week ending	Temperature during the week			Weekly total precipitation (in)	Weather
	Lowest	Highest	Average		
	(degrees F)				
9/6/65	33	84	57	0.00	Rainy at the beginning and end of the week.
9/13/65	35	81	55	0.32	Cool and damp weather with rain at the beginning and end of the week.
9/20/65	38	69	48	1.97	Light rain and showers throughout the week.
9/27/65	24	60	41	1.14	Intermittent rain throughout the week.
10/4/65	26	71	46	1.69	Rain over the first half of the week.
10/11/65	31	74	54	0.00	Dry and strong winds.
10/18/65	25	69	51	0.13	Showers at the end of the week.
10/25/65	20	70	47	0.09	Showers at the beginning of the week.
11/1/65	23	74	45	0.00	Dry and clear.

Courtesy of U. S. Weather Bureau State Climatologist, Brookings, South Dakota.

APPENDIX TABLE II

Chemical analysis of good hay of Spring 1964-65 (Phase I)

Sample No.	Fat	Crude fiber	Protein	Ash	Cal/gm
	%				
GM5	1.79	31.16	16.53	7.95	4.30
GM6	1.85	29.60	16.41	8.37	4.42
GM7	1.93	28.21	18.75	8.98	4.50
GM8	1.53	28.92	17.08	7.88	4.45
GM20A	1.51	22.94	21.44	9.40	4.32
GM20B	1.37	27.11	20.12	8.93	4.24
GM20C	1.55	23.83	25.84	9.52	4.33
GM20D	1.59	25.84	24.64	9.57	4.40
GM20E	1.41	21.89	23.67	9.28	4.33
GM20F	1.45	27.05	21.84	8.93	4.33
GM20G	1.64	24.21	23.33	8.97	4.37
GM20H	1.55	30.52	19.11	9.01	4.36
GM20I	1.26	31.03	24.89	8.06	4.27
GM20J	1.44	27.97	16.41	9.02	4.95
GM20K	1.71	25.20	23.37	9.43	4.34
GM20L	1.61	22.15	24.11	9.88	4.33
GM20M	1.91	28.70	20.41	9.47	4.29
GM20N	1.66	26.68	21.64	9.03	4.27
GM20O	1.79	23.12	23.85	9.37	4.28
GM21	1.64	25.79	21.93	9.03	4.44
Average	1.61	26.56	21.27	9.00	4.33

APPENDIX TABLE III

Chemical analysis of moldy hay of spring 1964-65 (Phase I)

Sample No.	Fat	Crude fiber	Protein	Ash	Cal/gm
	%				
GM9	1.17	32.32	16.11	13.47	4.11
GM10	1.28	36.89	21.61	11.49	3.74
GM11	1.04	36.24	21.69	10.62	4.24
GM12	0.93	30.11	20.29	10.54	4.26
GM22	0.92	28.95	16.89	15.27	3.79
GM23	0.91	27.85	18.52	14.23	3.89
GM24	1.00	27.06	18.77	14.53	3.39
GM25	0.73	27.09	16.54	14.74	3.80
GM26	0.87	27.38	20.77	12.50	8.85
GM27	1.70	29.96	20.62	12.11	3.78
GM28	1.62	27.03	23.41	12.17	3.97
GM29	1.69	28.20	23.86	12.19	3.93
GM30	1.79	27.59	22.39	12.73	3.97
GM31	1.48	30.08	20.63	11.22	4.11
GM32	1.38	29.68	17.71	12.41	3.98
GM33	0.90	27.20	18.36	14.28	4.09
GM34	1.43	25.31	17.97	12.39	4.02
GM35	1.17	28.22	20.31	12.02	4.05
GM36	1.43	27.09	19.29	14.66	4.07
GM37	1.08	25.25	18.75	14.64	4.13
Average	1.23	28.96	19.72	12.91	3.96

APPENDIX TABLE IV

Chemical Analysis of Low Moisture Silage of Spring 1964-65

(Phase I)

Sample No.	Fat	Crude fiber	Protein	Ash	Cal/gm
	%				
GM1	3.03	21.61	21.01	11.74	4.22
GM2	2.83	22.73	20.45	11.23	4.25
GM3	2.27	22.82	20.39	11.44	4.17
GM4	2.89	22.44	20.76	11.42	4.16
GM13C	2.49	20.87	10.10	10.79	4.28
GM13F	3.13	24.07	20.14	10.94	4.21
GM13I	3.14	22.16	19.98	11.28	4.24
GM14A	2.43	20.61	20.21	11.89	4.30
GM14A	2.96	21.77	21.31	10.75	4.12
GM14G	2.63	21.75	23.54	11.53	4.29
GM15B	2.47	20.76	19.87	10.62	4.28
GM15E	3.00	21.30	19.73	10.70	4.19
GM15H	2.56	23.08	19.74	10.56	4.64
GM15J	2.58	21.85	20.01	11.30	4.37
GM16A	2.43	21.08	20.10	10.74	4.27
GM16D	2.90	21.99	19.86	11.11	3.87
GM16G	2.55	20.58	19.99	11.24	4.17
GM17C	3.11	20.56	21.92	10.91	4.25
GM17F	2.53	21.28	20.25	11.38	4.28
GM17I	2.51	20.73	19.84	11.11	4.04
Average	2.72	21.70	20.46	11.13	4.23

APPENDIX TABLE V

Chemical Analysis of alfalfa samples from the field (Phase II)*

Sample No.	Moisture	Fat	Crude fiber	Protein	Ash	Cal/gm
	%					
GM41	52.10	2.81	25.99	20.37	9.89	4.24
GM42	49.50	2.09	25.37	17.84	10.14	4.08
GM43	55.20	2.01	23.03	20.31	10.14	4.99
GM44	53.10	1.94	24.55	19.60	9.66	4.23
GM47	44.50	2.04	26.60	17.02	10.96	4.16
GM48	49.70	2.14	25.50	20.07	10.28	4.16
GM50	47.70	2.07	26.80	19.31	9.42	4.20
GM51	51.90	2.13	24.95	18.62	10.21	4.17
GM53	49.10	1.92	26.00	19.48	10.16	4.18
GM55	44.70	1.58	25.21	21.01	9.87	4.25
Average	49.75	2.07	25.40	19.36	10.07	4.27

*Dry weight basis, samples just before ensiling.

APPENDIX TABLE VI

Chemical analysis of good hay (Phase II)

Sample No.	Moisture	Protein	Crude fiber	Fat	Ash	Cal/gm
	%					
GM58	20.00	19.21	27.32	1.55	8.97	4.02
GM61	14.60	19.02	29.44	1.57	9.06	4.03
GM64	17.10	18.93	31.10	1.63	8.94	4.23
GM66	14.40	19.96	29.17	1.74	8.81	4.29
GM69	14.20	17.88	23.51	1.46	7.83	4.16
GM72	14.00	19.21	29.08	1.49	8.61	4.16
GM75	12.80	19.24	29.42	1.74	8.75	4.23
GM78	9.20	16.78	31.24	1.47	7.88	4.21
GM81	12.10	16.61	33.66	1.31	8.04	4.08
GM84	13.80	17.22	30.63	1.88	8.62	4.11
GM87	9.60	17.86	29.77	1.70	8.61	4.01
GM90	10.20	18.91	28.66	1.92	9.11	4.10
GM93	12.40	18.66	28.68	2.09	8.50	4.06
GM96	12.00	17.13	30.50	1.74	8.66	4.06
GM99	10.60	17.27	33.84	1.66	8.73	4.25
GM102	11.55	17.31	30.70	1.86	8.82	4.16
GM105	11.90	17.01	32.33	1.88	9.31	4.26
GM108	10.10	17.00	32.05	1.73	9.48	4.22
GM111	10.75	16.25	32.83	1.55	9.82	4.22
GM114	9.60	16.85	29.17	1.58	10.14	4.12
GM117	10.10	1.79	30.81	15.70	8.04	4.15
GM120	8.65	1.68	32.51	14.76	9.14	4.13
GM123	8.55	1.80	30.21	16.53	8.38	4.21
Average	12.09	1.64	30.29	17.62	8.79	4.15

APPENDIX TABLE VII

Chemical analysis of moldy hay fed (Phase II)

Sample No.	Moisture	Fat	Crude fiber	Protein	Ash	Cal/gm
	%					
GM59	15.70	1.42	23.68	18.76	8.12	4.14
GM62	14.90	1.34	24.74	17.43	9.42	4.03
GM65	17.70	1.81	31.11	18.52	9.34	4.22
GM67	17.20	1.73	30.67	18.41	10.08	4.15
GM70	14.70	1.94	30.91	17.11	9.22	4.04
GM73	18.20	1.64	30.32	17.21	9.99	4.06
GM76	17.20	1.23	31.15	17.54	9.11	4.13
GM79	11.25	1.22	31.92	16.97	9.08	4.11
GM82	14.80	1.30	29.51	18.46	8.67	4.08
GM85	15.50	1.35	22.61	17.97	9.38	4.04
GM88	10.00	1.23	28.98	18.91	8.96	4.03
GN91	10.80	1.70	29.34	17.77	9.10	3.96
GM94	14.30	1.53	30.95	17.55	9.85	4.02
GM97	14.40	1.43	32.45	21.59	9.09	4.09
GM100	12.10	1.43	34.69	17.48	10.83	4.22
GM103	11.30	1.41	34.49	17.40	10.36	4.24
GM106	13.70	1.30	35.56	17.23	9.54	4.21
GM109	13.25	1.21	32.39	17.91	9.61	----
GM112	12.85	1.39	30.91	18.34	9.03	4.14
GM115	12.30	1.36	34.99	16.89	9.21	4.17
GM118	12.70	1.56	31.34	17.48	9.56	4.18
GM121	11.80	1.42	31.89	17.68	9.08	4.11
GM124	13.40	1.39	31.77	16.27	9.95	4.12
Average	13.91	1.45	30.71	17.86	9.42	4.11

APPENDIX TABLE VIII

Chemical analysis of low moisture silage (Phase II)

Sample No.	Moisture	Fat	Crude fiber	Protein	Ash	Cal/gm
				%		
GM56	38.20	1.50	26.94	21.05	11.03	4.18
GM57	41.20	1.72	25.76	21.20	10.88	4.07
GM60	40.60	2.01	32.80	20.39	10.45	3.98
GM63	44.90	2.09	30.45	20.53	11.54	4.12
GM68	46.60	2.22	27.96	20.23	10.67	4.18
GM71	48.10	2.72	25.39	18.60	10.79	4.11
GM74	50.00	2.28	-----	19.01	10.73	3.97
GM77	49.50	2.49	27.08	18.77	11.07	4.11
GM80	50.70	2.38	27.31	17.99	10.86	4.33
GM83	49.70	3.03	26.29	18.64	10.86	3.97
GM86	49.45	3.14	33.08	18.68	10.48	4.09
GM89	48.40	3.27	26.67	18.65	10.16	4.06
GM92	44.80	3.26	25.54	18.72	10.10	4.04
GM95	49.10	2.75	26.15	18.88	10.42	4.08
GM98	48.10	2.87	26.88	15.58	10.36	4.12
GM101	47.00	2.78	27.27	19.87	10.56	4.27
GM104	46.75	2.69	26.84	19.66	10.91	4.30
GM107	47.30	2.84	26.94	19.88	10.92	4.26
GM110	48.35	2.61	25.91	19.07	10.23	4.22
GM113	46.45	2.31	28.16	18.67	9.99	4.16
GM116	48.75	2.59	26.45	18.43	9.88	4.24
GM119	50.10	2.83	27.02	-----	10.61	4.28
GM122	46.40	2.52	26.13	19.49	9.80	4.23
GM125	48.30	2.39	24.88	20.14	9.84	4.22
Average	47.01	2.55	27.30	19.22	10.55	4.15

APPENDIX TABLE IX

Chemical composition of the phosphorus supplements used during the feeding trial

Ingredients	Dicalcium phosphate (Digesta 18½P)	Sodium phosphate (Stauffer Chemicals)
	%	
Minimum phosphorus	18.5	25.0
Minimum calcium	22.0	----
Maximum calcium	27.0	----
Minimum sodium	----	31.0
Maximum fluorine	0.02	25 ppm