1968

The Feeding Value of High Dry Matter Corn Silage

Myers J. Owens

THE FEEDING VALUE OF HIGH
DRY MATTER CORN SILAGE

BY

MYERS J. OWENS

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

1968

2661-23

THE FEEDING VALUE OF HIGH

DRY MATTER CORN SILAGE

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 Advisor Date

Head, Dairy Science Department Date

ACKNOWLEDGMENTS

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

The generous assistance of Dr. Neal Jorgensen with the chemical analysis and supervision is gratefully acknowledged.

Assistance with feeding and weighing the animals by Roy Kundel is greatly appreciated.

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TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF TABLES

INTRODUCTION

The importance of corn in dairy cattle feeding is generally acknowledged. A popular way of preserving the crop is to make corn silage, thus using the whole plant for feed and preserving maximum feed per acre.

The increased utilization of corn silage by dairymen may be due to its high energy yields per acre, high acceptability by cattle, and ease with which it is incorporated into automated systems of harvesting and feeding. The increasing importance of corn silage in the United States is evidenced by the increasing acreages harvested as corn silage. In 1950 there were 4,937,000 acres planted with a yield of 31,002,000 tons harvested as corn silage. In 1965 there were 8,035,000 acres with a yield of 84,266,000 tons harvested (1). In South Dakota 56,691 acres of corn silage were planted in 1930 with a yield of 310,254 tons. In 1964 there were 952,883 acres harvested with a yield of 4,796,641 tons (41).

With the large increase in corn yields in recent years, it appeared beneficial to examine some new techniques of handling and processing this crop. Because later harvest dates may be advantageous to work schedules and availability of silo storage space, this research was designed to investigate the effect of delaying harvest of corn silage beyond normal plant maturity in terms of changes in chemical composition with increasing plant maturity, field and nutrient losses, feeding value, and digestibility.

REVIEW OF LITERATURE

In order to more properly evaluate the nutritive value of forages, considerable research emphasis has been placed on forage research during the past 20 years. Considerable progress has been made in establishing relationships of chemical constituents to intake and digestibility under specific conditions, but a satisfactory scheme which will consistently predict animal performance has not been well established.

It now seems well established that the nutritive contribution a forage will make toward meeting an animal's needs depends upon its composition, rate of intake, and efficiency with which the animal uses the ingested nutrients. The following discussion is a review of research designed to answer the principal questions in this area with regard to corn silage.

Stage of maturity and chemical composition

As harvested. Several workers (3, 10, 11, 21, 22, 26, 32) studied the changes in the chemical composition of the whole corn plant and various parts of the plant with stage of maturity. Hopper (22) conducted studies on the progressive development of the corn plant with respect to chemical composition and relative production of the ear, stover, and fodder between the tassel and ripe stage of maturity. Because of the detail of this study, a summary of the change in chemical composition of the ear, stover, and fodder appear in Table 1.

Table 1

Average composition of the ear, stover and whole corn plant (22).

Stage of Maturity	Dry matter %	Ash %	Crude protein %	Ether extract %	Crude fiber %	N.F.E. %
		Composition of dry matter				
Ear						
Tassel	-----	----	-----	----	-----	-----
Milk	20.14	3.03	12.30	2.45	18.86	63.36
Dough	38.11	1.95	10.82	3.30	11.83	72.10
Glazed	50.38	1.59	10.68	4.03	9.57	74.13
Ripe	58.16	1.56	10.49	4.29	8.59	75.07
Stover						
Tassel	-----	----	-----	----	-----	-----
Milk	18.07	7.42	8.02	1.33	28.04	55.19
Dough	20.28	7.92	6.45	1.45	29.77	54.41
Glazed	24.09	9.26	5.93	1.28	33.53	50.00
Ripe	32.75	9.12	5.44	1.30	34.37	49.77
Fodder						
Tassel	13.48	8.53	11.65	1.68	27.66	50.48
Milk	18.47	6.49	8.95	1.57	26.08	56.91
Dough	25.02	5.51	8.22	2.20	22.52	61.55
Glazed	32.72	5.38	8.33	2.67	21.42	62.20
Ripe	43.01	5.00	8.19	2.94	20.29	63.58

As can be seen in Table 1, the per cent crude protein, crude fiber and ash decreased while that of dry matter, ether extract, and nitrogen-free extract increased in the ear and whole plant with increasing maturity. Similar trends can be observed for the stover with the exception of an increase in ash and crude fiber; and a decrease in ether extract and nitrogen-free extract.

Hopper (22) reported the percentage distribution of constituents between ears and stover of corn harvested at five stages of maturity. At the dough stage, whole plant dry matter content of 25.02%, the ears represented 40.46% of the dry matter and the stover 59.54%. The percentage of dry matter in the ears and stover at the ripe stage, with whole plant dry matter at 43.01%, was 54.59 and 45.51%, respectively. With increase in stage of maturity the ear contributed a larger percentage of the dry matter, crude protein, ether extract, and nitrogen-free extract and less crude fiber and ash in comparison with the contribution from the stover.

Hopper (22) further stated that the fodder did not reach its greatest dry matter yield per acre until the glazed stage of maturity. The corn grain was the most valuable part of the plant for feed. It made its greatest development after the milk stage of maturity. The ears accounted for the increase in yield between the milk and glazed stage. Taking the maximum yield of dry matter in the fodder as 100%, the relative yield in the dough stage was 86.7% and at the ripe stage the yield was 93.5% of maximum. At the glazed stage of maturity the ears had become equal to the stover in dry matter. Hopper further stated that ensiling of corn should not be delayed after the glazed stage as a mechanical loss of dry matter occurs.

Aldrich (3) studied maturity of corn grain to determine the stage at which the kernel dry matter content was maximum. His data indicated that the yield of the corn grain continues to increase until the dry matter content in the grain averaged 65%. Until maturity is reached chemical composition of the grain and plant can be expected to change.

Recent reports (10, 11, 21, 26, 29, 37) show chemical changes that take place in corn grain and corn plants with increasing maturity.

Bryant et al. (11) studied the composition of immature corn, 21.8% dry matter, and mature corn, 32.0% dry matter. Changes in chemical composition were similar to those reported by Hopper (22) for comparable stages of maturity.

Johnson et al. (26) studied the changes in dry matter and protein distribution in the corn plant at six stages of maturity in 1962 and eight stages in 1964. Changes in dry matter per cent from July 20 to October 14 were 14 to 36 for stalks, 19 to 79 for leaves and 10 to 62 for ears. Highest total dry matter yield per acre appeared to be between the dent and glazed stages. In both years the ears constituted over 60% of the dry matter at maturity, but did not reach this level until September 12, 1962 and October 6, 1964. The stalks lost moisture very slowly throughout the period of ear maturation. The leaves lost moisture at a slightly faster rate during ear maturation and very rapidly after a killing frost. The dry matter content of ears increased at a rapid and constant rate. At the point of maximum acre yield, the dry matter content of the stalks, leaves, and ears was approximately 20, 28, and 50%, respectively. Prior to tasseling the corn plant resembled other forage plants with a relatively high crude protein content of 16 to

20% in the leaves. The protein content in the leaves declined rapidly from 11.0 to 7.5% at maturity. The protein content of stalks was between 11 and 12% prior to tasseling, declining rapidly until 15 days after tasseling and declining only slightly throughout the remainder of ear growth and maturation. In this study the protein content of the ears of a single plant reached a maximum on October 6, whereas the protein content of the total plant reached a maximum on September 9 after which it declined. This work suggests the possibility of dilution of protein by other dry matter constituents, but the decline in total protein in the whole plant is not explained.

Maximum yield of dry matter per acre appeared to occur between the dent and glazed stages of maturity. Although yield declined after the glazed stage the per cent ears in overall material did not decline but actually increased slightly.

Benne et al. (10) reported the chemical change in corn plant parts on a dry matter basis at three stages of maturity. The plant was separated into ears, upper leaves, lower leaves, upper stalks and lower stalks. The crude protein of stalk parts decreased from 7.8% on July 24 to 2.7% on October 6. Leaf crude protein decreased from 18.7 to 6.3%. These changes are similar to those reported by Hopper (22).

Lebedeva and Zubkova (29) reported changes in amino acid content of corn grain with advancing maturity. Glutamic acid, alanine, and valine levels increased; aspartic acid, serine, tyrosine, and phenylanine levels decreased; and arginine, threonine, and glycine showed little change as corn grain matured.

Mineral changes associated with maturity have been investigated by Steger (39) and Benne et al. (10). Steger (39) reported that potassium, sodium, calcium, total phosphorus, and lipid phosphorus decreased during ripening. Phytin phosphorus increased and accounted for 70% of all phosphorus at maturity in corn grain.

Benne et al. (10) investigated the mineral composition of various parts of the corn plant. Calcium, copper, iron, magnesium, manganese, sulfur, and zinc levels increased with maturity while chloride, potassium, and phosphorus contents decreased in both upper and lower leaves. Lower leaves were higher in ash and ether extract than upper leaves but both showed similar effects of aging. Upper and lower parts of corn stalks showed increases in per cent ash and crude fiber and decreases in nitrogen-free extract, ether extract and crude protein with maturity.

Thornton et al. (40) reported that much of the decrease in ash content, with ripening, is due to a change in potassium. Nearly all minerals become less concentrated as starch is deposited in the kernel.

As silage. Johnson et al. (28) studied the chemical composition of corn silage at seven stages of maturity, from 20.9 to 49.2% DM (post-frost). Crude protein content of silage was lower with advanced stages of maturity. As dry matter content of silage increased the per cent total acid production decreased. Total acid production was highest at the early milk stage.

Gordon et al. (21) studied the change in composition of the corn plant as ensiled and as fed at two stages of maturity. Normal silage contained 23.6% dry matter and late harvested corn silage contained 58.2% dry matter. The wetter silage increased in dry matter, crude protein, and acid detergent fiber during fermentation. The dry matter content of the high dry matter corn silage decreased during fermentation. The high dry matter silage had a higher pH and ammoniacal nitrogen content, but was lower in sugar, butyric, propionic, and acetic acid when compared with normal silage.

<u>Stage of maturity and field yields and losses</u>

Corn silage has traditionally been ensiled in early dent stage or when the plant contains less than 30-32% dry matter. The exact stage of maturity at which to harvest the corn plant for maximum yield is still in question. Early research indicated that losses of up to 27.8% of total dry matter and 43.5% of total nutrients occurred when corn was ensiled with a low dry matter content (5,6,36).

More recently, Gordon et al. (21) found a marked reduction in fresh weight and an increase in dry matter percentage as a result of delaying harvest. The most striking effect noticed was a lower dry matter yield per acre from the late harvested plots. In two trials, late harvested corn silage (58.3 and 60.0% DM) showed a field dry matter loss of 18.7 and 27.2%, respectively.

Byers and Ormiston (13) compared corn silage harvested at 31.5 (control) and 54.9% (mature) dry matter. Yields of fresh silage and dry matter per acre were 22.2 and 6.9 tons, respectively, for the control and 12.9 and 6.21 tons, respectively, for the mature corn silage. A loss of 500 lb of dry matter per acre with the mature silage was primarily due to entire plants being lodged and not picked up by the forage chopper.

The effect of stage of maturity of corn silage on yield was studied by Geasler et al. (18). Mid-September harvested silage, 28% DM, yielded 1,880 kg of dry matter per hectare, whereas mid-October silage, 48% DM, yielded 1,681 kg per hectare, a reduction of 10.6%. Mid-November silage, 60% DM, yielded 1,494 kg per hectare, a reduction of 20.5% from September and a reduction of 11.0% from October.

Perry et al (35) conducted yield studies starting 101 days after planting (August 24) and continued harvesting at weekly or biweekly intervals to February 22. Maximum yields were obtained at the November 2 harvest (171 days after planting) when corn was in the hard dent stage. Maximum yield of total plant dry matter occurred with the September 28 harvest (138 days after planting), 2930 kg per hectare to a low of 1290 kg per hectare, February 22. Maximum ear corn weight (2000 kg) was obtained September 28, and maximum kernel yield (1138 kg) was obtained September 28. Moisture level in the whole plant was highest on August 24 (80.5%) and decreased gradually to a low of 20.0% by February 22. Dry matter, as ear corn, lost per hectare ranged from 31 kg on October 17 to 392 kg on February 22.

Nevens et al.(33) showed that from August 28 to September 22 (25 days), the yield of fresh corn silage was almost unchanged, but the dry matter increased from 17.4 to 27.7%, and the portion formed by ears increased from 11.5 to 48.4%.

Woll (43) stated that yellow dent corn lost about 23.8% of its dry matter and 24.3% of the protein that it originally contained when the fodder was shocked and later fed out. Comparative lots of the same varieties of corn were put into silos. The loss of dry matter from the silo was 15.6% and the loss of protein was 16.8%.

Stage of maturity and feeding value

The nutritional value of corn silage is influenced by the stage of maturity of the plant at time of ensiling (6,31). Silage made from corn harvested at milk stage or earlier, supplies only 50 to 60% as much TDN per hundred pounds as the same crop harvested for silage at the dent stage (31).

Gordon et al. (21) did not find a consistent trend in dry matter intake in two trials comparing normal silage (26.3 to 32.4% DM) with late harvested corn silage (58.2 to 60.0% DM). Daily dry matter consumption as per cent of liveweight ranged from 1.54 to 1.36 and from 1.44 to 1.42; 4% fat corrected milk in pounds per day ranged from 51.1 to 49.5 and 49.5 to 47.3 for the normal and late harvested corn silage, respectively.

Similar dry matter intakes (16.1 lb vs. 16.6 lb) of mature corn silage (54.9% DM) compared to immature corn silage (31.5% DM) were reported by Byers and Ormiston (13). There was no difference in milk production between the two silages.

Byers and Ormiston (14) evaluated corn silage harvested at three stages of maturity. Average dry matter content of the silages as fed was 35.9, 44.1, and 51.8% for regular (R), late (L), and very late (VL) corn silage, respectively. Average daily dry matter consumption from R, L, and VL corn silage was 5.76, 4.5, and 4.77 kg, respectively. Dry matter consumed per 45.4 kg of body weight was R, 0.48; L, 0.38; and VL, 0.37 kg. Average daily 4% FCM favored regular silage: R, 18.0; L, 16.3; and VL, 16.6 kg. Organoleptic evaluation ranked the silages regular, very late, and late.

Bryant et al. (11) compared corn silage harvested at 21.7 and 31.8% dry matter. Average 4% FCM production for immature corn silage was 32.3 lb compared to 33.1 lb per day for mature corn silage. Persistency of milk production and dry matter consumption was higher for the mature corn silage.

Geasler et al. (19) harvested corn silage at 28, 48, and 60% dry matter in September, October, and November, respectively. Cattle fed the September harvested silage significantly outgained the October group (1.30 kg vs. 1.22 kg) and the November group (1.30 kg vs. 1.24 kg). The October group was not significantly different from the November group. Carcasses from the September group were significantly superior to October and November groups for all factors determining cutability. At each harvest date, identical silos were filled with fine and medium chop silage. Within harvest dates, average daily gain was 1.31 vs. 1.22, 1.26 vs. 1.19, and 1.26 vs. 1.22 kg for fine and medium chop in September, October, and November harvested silages, respectively.

Huber et al. (23) compared corn silage harvested at soft, medium and hard dough stages of maturity with dry matter contents of 25.4, 30.3, and 33.3%, respectively. Voluntary intake of silage dry matter increased as maturity of the corn plant at harvest increased. Average daily intake of silage dry matter, expressed as pounds per 100 pounds of body weight, was 1.95, 2.13, and 2.31 for soft, medium, and hard dough stages, respectively. Increases in milk yields were noted as maturity of silage increased from soft to hard dough. No significant changes, due to maturity of silage, were noted in milk composition, body weight gains, or efficiency of milk production.

Consumption of 1.48, 1.89, and 1.77 lb daily per 100 lb of body weight were noted by Noller et al.(34) from corn silage harvested in milk, very early dent and late dent stage of maturity, respectively. Heifers fed the immature silage outgained heifers fed the other two silages.

Stage of maturity and digestibility

The nutritive value of feeds obtained from digestion trials are not absolute values, but vary with such factors as level of intake, the physical form of the feed, frequency of feeding, presence of other ingredients in the ration and species of livestock used to evaluate the feedstuff (2, 16, 17, 42). Perhaps these factors explain some of the wide variations reported for the digestibility of corn silage.

Johnson et al. (27) conducted a study of the effect of corn plant maturity on in vitro cellulose digestibility. In 1963 four stages of corn were harvested from August 19 to October 4, just after a killing frost. In vitro cellulose digestibility of stalk cellulose declined until about 10 to 15 days after tasseling, after which it remained constant until frost. In vitro cellulose digestibility of leaf cellulose was higher than that of stalk cellulose and declined slowly but steadily throughout the entire period. Ensiling did not appear to lower the in vitro cellulose digestibility.

The apparent dry matter digestibilities of corn silage harvested in milk, very early dent and late dent stages were reported by Noller et al. (34) as 72.3, 69.7, and 68.7%, respectively. Crude protein digestibility ranged from 68.4% in the milk stage to 55.3% for the late dent stage.

Byers and Ormiston (13) reported corn silage harvested at 31.5 and 54.9% dry matter to have dry matter digestibilities of 62.7 and 56.7%, respectively.

Huber et al. (23) noted no significant difference in dry matter digestibilities nor in the digestibilities of the dry matter components in corn silage harvested at 25.4, 30.3, and 33.3% dry matter, respectively.

Bryant et al. (12) in a two year study with immature corn silage averaging 21.8% dry matter and mature corn silage averaging 32.0% dry matter, found dry matter digestibilities to be 66.7 and 68.6%, respectively. Apparent digestibilities of other dry matter constituents were: crude protein, 57.4 and 63.9; crude fiber, 70.8 and 63.2; nitrogen-free extract, 68.4 and 75.0; and ether extract, 74.0 and 73.6%, respectively, for the two silages.

Gordon et al. (21) used sheep to study the digestibility of normal corn silage (26.3% DM) and late corn silage (58.2% DM). Dry matter digestibility was 70.3 and 68.8%; acid detergent fiber, 63.1 and 60.1%; and crude protein, 57.2 and 55.6% for the normal and late silages, respectively.

Caldwell and Perry (15) harvested corn silage at ten stages of maturity starting 101 days after planting (August 24) and continuing until February 22 to evaluate the possible changes in digestibility as the corn plant matured. Dry matter digestibility was 71.06 and 68.41%; crude protein, 55.96 and 53.79%; ether extract, 78.52 and 85.31%; crude fiber, 63.03 and 54.83%; nitrogen-free extract, 78.52 and 74.07%; respectively for the earliest and latest cut corn silage. The dry matter content of the silages from the respective harvest dates ranged from 20.09 to 80.28%.

EXPERIMENTAL PLAN

Objectives of the experiment

The objectives of this study were: (1) to determine field yields and losses of corn silage harvested at different dry matter contents; (2) to compare chemical quality of the corn silage; (3) to determine the relative feeding value of high dry matter corn silage when fed to lactating dairy cattle as measured by dry matter intake, milk production, and body weight changes; and (4) to determine the digestibility of the silage dry matter, protein, fiber and energy.

Pre-experimental classification of the silages at different dry matter contents were: low dry matter corn silage (LDMCS), less than 32% DM; medium dry matter corn silage (MDMCS), 32-42% DM; and high dry matter corn silage (HDMCS), more than 42% DM.

Experimental procedure

Harvesting and storage. Each year a 24.0 acre field of well-eared hybrid yellow corn was divided into six plots of 4.0 acres each. In 1965 (Trial I), and 1966 (Trial II) three of the plots were harvested as MDMCS and three as HDMCS. A conventional field chopper was used to harvest each silage. Each year the HDMCS was ground with a hammermill using a 1.0 to 1.5 inch screen before ensiling. All silages were stored in gas-tight units.

Field yields and losses. Each year the yield from each plot was determined by area measurement and by weighing and sampling every load for determination of the dry matter content. Field losses were determined by weighing the material in a 64 square foot area after harvest and sampling each area for dry matter content. The samples were collected at 200 foot intervals with and against prevailing winds. Twenty-six areas were sampled per plot.

The percentage of ears on the ground were determined by counting the ears on 100 stalks and the ears on the ground in the same area before harvesting the HDMCS in Trial I. This count was taken every 150 feet with and against the prevailing wind. A measurement of ear losses before and after harvest were determined in Trial II for each harvest date. This was done by counting the ears on the stalks before harvest and on the ground after harvest in the same area. Stalks were counted at the same interval as in Trial I. The per cent stalks with ears were determined by counting the ears on 100 stalks at same intervals as described in Trial I. This count was used to calculate the per cent stalks with ears.

Trial I design. Trial I involved a continuous feeding trial as suggested by Lucas (30), using a 21-day standardization period, a 119-day experimental period and a 14-day post-experimental. The standardization period was conducted to permit adjustment by covariance for differences between groups at the start of the comparison period. During the standardization period all animals were fed 10 lb alfalfa hay, MDMCS ad libitum, and grain (50% corn, 30% oats, 2.5% beet pulp, 15% soybean meal, 0.6% dicalcium phosphate, 0.6% bone meal, 1.2% trace-mineralized salt, and 2,200 IU of vitamin

A per lb of feed) at the rate of 1 pound for each 2.5 pounds of 4% fat-corrected-milk produced. Three-year-old animals were given an additional 2 pounds of grain daily. Subsequent grain adjustments were made every seven days on the basis of average production decline for all cows. At the end of the standardization period the 20 Holstein cows were paired on the basis of milk production, stage of lactation, and age, and one member of each pair was assigned at random to each experimental treatment. The experimental treatments were MDMCS and HDMCS. Alfalfa hay and grain were fed at the same levels as during the standardization period. Grain adjustments were made every 14 days. Grain, hay and silage were fed twice daily and weighbacks taken once daily.

The animals were kept in groups of 10, group fed, and housed in a free stall barn.

Feedstuffs were sampled once weekly as fed for dry matter determination. The per cent dry matter times daily intake was used to calculate average daily dry matter intake of feedstuffs. The dried sample was ground and used for proximate analysis. A fresh sample of silage was taken at the same time for pH and carotene analysis.

Milk weights were recorded daily. A composite of an AM and PM milk sample was used for determination of the per cent milk fat and solids-not-fat. Average daily milk production and the milk fat per cent was used to calculate the average daily production of milk fat and 4% fat-corrected-milk.

Each cow was weighed three days in succession at the end of the standardization period and weeks 4, 8, 12, and 17. The average of these weights was used to determine changes in body weight during the experimental period. They were also used to determine dry matter intake per hundred pounds of body weight.

Trial II design. Trial II involved a double-reversal design with five-week periods, including a one week adjustment period. Twenty lactating Holstein cows were divided into two groups balanced according to milk production, stage of lactation, and age. The groups were accustomed to being fed corn silage (MDMCS) as their only source of roughage for three weeks before the experiment began.

The grain feeding level was 1 pound for each 3 pounds of 4% fat-corrected milk produced. Allowance for growth was the same as Trial I. Grain adjustments were made every seven days. The grain composition was 47.5% corn, 32.5% oats, 17.5% soybean meal, 1.3% dicalcium phosphate, 0.6% bonemeal, 0.6% trace-mineralized salt, and 2,200 IU of vitamin A per pound of feed. Grain and silage were fed twice daily and weighbacks taken once daily. Feedstuffs, milk sampling, and chemical analyses were conducted as in Trial I. Each animal was weighed on three consecutive days at 1 PM at the beginning and end of each experimental period.

Digestion trial. In Trial II, four Holstein steers were fed the experimental forages in three conventional total-collection digestion trials simultaneously with the feeding trial. The animals were confined to individual metabolism stalls that permitted the total-collection of feces and urine.

The length of each digestion trial was 21 days, including a 14-day preliminary period, followed by a seven-day collection period. A two-day exercise period was allowed between each 21-day trial. During this time only MDMCS was fed.

During each digestion trial, silages were fed twice daily at 7:00 AM and 5:00 PM. Feces excreted by each steer were measured and sampled during the collection period. The moisture content of feed and feces samples was determined by drying in a forced-air oven at 48 C for 48 hours.

Chemical analysis. Nitrogen was determined on fresh silage samples using the methods approved by AOAC (4). Energy values were determined using a Parr oxygen adiabetic bomb calorimeter. Milk fat was determined by the Babcock procedure (4), and solids-not-fat by the Golding (20) procedure. Weekly collected samples of forage and grain as fed were used for proximate analyses according to standard AOAC methods (4). Dry matter was determined by using toluene-distillation technique and oven-drying (48 C for 48 hr). The carotene content of the silage was determined by the AOAC method (4).

The concentration of volatile fatty acids in the silages were determined by gas-liquid chromatography, as reported by Baumgardt (9). Lactic acid was measured by the colorimetric method of Barker and Sommerson (8). Hydrogen ion concentration, expressed as pH, was determined with a conventional glass electrode pH meter.

Statistical analysis. Statistical analysis as outlined by Snedecor and Cochran (38) were used. All data were analyzed on a within trial basis.

RESULTS AND DISCUSSION

Harvest yields and losses. Average forage yields and losses per acre for the experimental silages for Trials I and II can be seen in Table 2. Although harvest dates were similar, a marked difference in fresh weight and dry weight of experimental silages occurred between years. This difference is possibly due to differences in corn varieties and weather conditions between years since the corn was raised on the same plots of ground each year with the same fertilization treatment.

A marked reduction in fresh weight and an increase in dry matter per cent was observed in both years as a result of delaying harvest. These changes were expected and can be explained on the basis of maturation of the plant. However, the most striking effect was the lower dry matter yield from the late harvested silage. This is similar to the findings reported by Gordon et al. (21) and Byers and Ormiston (13). The HDMCS yielded 61.7% of that of the MDMCS on a fresh weight basis and 95.9% of the MDMCS on a dry matter basis in Trial I. In Trial II the fresh weight (25,667 lb/acre) was greater than that found in Trial I (20,231 lb/acre) and the yield of HDMCS on a fresh weight and dry weight basis were less than in Trial I. The yield of HDMCS on a fresh weight basis was 32.1% of that of MDMCS and on a dry matter basis 55.8% of the MDMCS yield in Trial II.

Table 2

Forage yields

Harvest	Harvest date	Yield per acre					
		Fresh weight as ensiled lb	Dry matter %	Dry weight as ensiled lb	Dry matter loss lb	Total dry matter yield lb	Dry matter loss %
Trial I							
MDMCS	9-24	20,238**	39.1**	7913	586**	8499	6.9**
HDMCS	11-5	12,489**	60.8**	7594	1622**	9216	17.6**
Trial II							
MDMCS	9-24	25,667**	38.3**	9831**	517**	10348**	5.0**
HDMCS	11-4	8,238**	64.0**	5272**	1794**	8066**	25.4**

Treatment values within a trial followed by ** are significantly different (P < 0.01).

The dry matter loss per acre was significantly ($P < 0.01$) greater for HDMCS than for MDMCS, 17.6% compared to 6.9% in Trial I and 25.4% compared to 5.0% in Trial II, respectively. These losses are similar to those reported by Geasler et al. (18), Perry et al. (35), and Gordon et al. (21). The losses were mainly due to leaf and ear droppage, however, some whole plants were lost due to wind damage. The chopper left more plant material when traveling in the same direction as the prevailing wind. The forage chopper was unable to pick up all of the downed stalks during the harvesting of the HDMCS.

The per cent stalks with ears before harvest for the MDMCS was 78.8 and for the HDMCS 73.0 in Trial II, (Table 3). Percentage of ears on the ground before harvest of the HDMCS was 6.6 in Trial I. However, in Trial II the 10.1% ears on the ground for stalks with ears after harvesting the HDMCS was significantly ($P < 0.01$) higher than the 1.10% found before harvesting HDMCS and the 0.90% after harvesting MDMCS.

Chemical composition of the forages. The average chemical composition of all feedstuffs as fed during Trial I and II are summarized in Table 4. The difference in yield (Table 2) and chemical composition (Table 4) of the corn silages within and between years may have been due to varietal and weather differences, as well as, changes in grain to forage ratio caused by field loss of plant parts. Hopper's (22) data indicates that the leaves are higher in

Table 3

Ear losses before and after harvest, Trial II

Item	MDMCS Before	MDMCS After	HDMCS Before	HDMCS After
Stalks with ears (%)	78.8[a]	----	73.0[b]	----
Ears on ground per:				
100 stalks (No.)	0.55[a]	0.70[a]	0.80[a]	7.40[b]
100 stalks with ears (No.)	0.55[a]	0.70[a]	0.80[a]	7.40[b]
100 stalks (%)	0.55[a]	0.70[a]	0.80[a]	7.40[b]
100 stalks with ears (%)	0.70[a]	0.90[a]	1.10[a]	10.10[b]

Values followed by the same letter are not significantly different ($P < 0.01$).

Table 4

Average chemical composition of feedstuffs as fed

		Dry matter composition					
Item	DM	Crude protein	Crude fiber	Ether extract	Ash	N-free extract	Carotene
	%	%	%	%	%	%	mcg/g
Trial I							
MDMCS	38.7**	7.3	22.5	2.1	3.8	64.3	2.0
HDMCS	60.0**	7.6	21.9	1.5	3.3	65.7	1.6
Alfalfa	88.1	15.1	29.7	1.3	7.6	46.3	
Grain mixture	89.4	13.7	8.5	4.5	6.5	66.8	
Trial II							
MDMCS	36.4**	8.4*	23.1*	2.1*	5.8*	60.5*	13.4**
HDMCS	63.5**	7.9*	22.2*	1.8*	3.8*	64.3*	3.1**
Grain mixture	88.9	20.3	6.7	3.8	5.5	63.7	

Values for the MDMCS and HDMCS within a trial followed by * or ** are significantly different at the 5% level and 1% level, respectively.

protein content than any other parts of the plant. Since leaves made up the largest percentage of the field losses, this may explain the difference in crude protein content of the silages between years. In Trial II, crude protein content of the silages were similar to the findings reported by most workers (11, 21, 35). The HDMCS was lower in crude fiber, ether extract, ash and carotene in both trials. The lower ash content may explain why cows fed HDMCS consumed more mineral offered free choice than cows offered MDMCS (0.16 lb compared to 0.01 lb per cow per day). The mineral offered free choice consisted to two parts dicalcium phosphate to one part trace-mineralized salt. The decrease in ash content, with increasing plant maturity, agrees with the work of Hopper (22), Benne et al. (10), and Thornton et al. (40). They reported that the ash content of the ears decreased with advanced maturity and that most of the decrease in ash is due to changes in potassium content. Nearly all minerals became less concentrated as starch was deposited in the kernel. The lower ash content of the HDMCS may be explained by an increase in percentage of dry matter from ears which contain less ash than the stalks.

Both silages were low in carotene content during Trial I. The carotene content of the HDMCS was significantly ($P < 0.01$) lower than that of MDMCS (3.1 vs. 13.4 mcg/g) in Trial II.

Chemical quality of the silages fed during Trial II is summarized in Table 5. A lower pH and a higher concentration of

Table 5

Average chemical quality of the silages as fed, Trial II

Silage	pH	Organic acid content of dry matter			
		Acetic	Lactic	Total	L/T
		%			
MDMCS	3.88*	1.67*	7.26*	8.93*	.81
HDMCS	4.18*	0.64*	4.83*	3.47*	.88

Values followed by * are significantly different ($P < 0.05$).

total organic acid would indicate a greater fermentation in the MDMCS. The pH of the silages in Trial I was 3.9 for MDMCS and 4.4 for HDMCS, similar to that of Trial II. The per cent acetic acid in each silage, HDMCS 0.64% and MDMCS 1.67% was similar to that reported by Gordon et al. (21). Huber et al. (23) also reported a higher pH for corn silage made at the hard dough stage of maturity when compared to corn silage made at an earlier stage of maturity. The lactic acid to total acid ratio was slightly higher for the HDMCS. This indicated a desirable fermentation even though total acid concentration was less than that for the MDMCS. Both silages were of excellent quality and were readily accepted by all animals.

Cow performance. The results in Table 6 indicate that cows fed HDMCS voluntarily consumed more forage dry matter, significantly ($P < 0.05$) more during Trial II, than cows fed MDMCS. Low ad libitum

Table 6

Average daily response of cows fed experimental forages

Response	Trial I MDMCS	Trial I HDMCS	Trial II MDMCS	Trial II HDMCS
Dry matter intake (lb/day)				
Silages	13.2	13.6	26.8*	29.0
Hay	7.9	7.7	----	----
Concentrate	15.4	15.4	12.1	12.5
Total	36.5	36.7	38.9*	41.5*
Dry matter intake (lb/100 lb BW)				
Silage	.93	.97	1.78*	1.92*
Hay	.56	.55	----	----
Concentrate	1.09	1.10	.82	.83
Total	2.58	2.62	2.60*	2.75*
Milk production (lb/day)				
Milk	36.3	37.4	31.7**	34.5**
4% FCM	35.2	35.2	33.7**	36.5**
Milk composition (%)				
Milk fat	3.9	3.8	4.4	4.4
Milk SNF	8.7	8.6	8.9	8.9
Body weight gain (lb/day)	.72	.88	.88**	1.63**

Treatment values within a trial, followed by * or ** are significantly different at the 5% and 1% level, respectively.

consumption of silage, less than 38% of total dry matter intake in Trial I could have been due to feeding alfalfa hay as part of forage and the feeding of high grain levels. No difference in 4% FCM production was noted in Trial I. Corn silage made up nearly 70% of the dry matter consumed in Trial II. Associated with the significantly ($P < 0.05$) higher total dry matter intake by cows fed HDMCS, primarily due to a higher silage dry matter intake, was a significantly ($P < 0.01$) higher level of 4% FCM production. This is in contrast to the findings of Gordon et al. (21). This may be explained in part by the difference in the method of handling the HDMCS before ensiling. Grinding the HDMCS before ensiling, in this experiment, facilitated packing of the silage which should be beneficial to fermentation. Geasler et al. (18) reported that the kilograms of dry matter stored per M^3 of silo capacity was greater when silage was finely chopped (1.00 cm) than when a medium chop was used (1.34 to 2.01 cm), regardless of harvest date. They also reported (19) that within harvest dates average daily gain of steers was greater for those fed finely chopped corn silage. Grinding the HDMCS before ensiling in this experiment prevented separation upon ensiling and selection of plant parts when fed. Both separation and selection of plant parts occurred when corn containing over 40% dry matter was harvested with a conventional forage chopper and stored in an upright silo. As noted by Gordon et al. (21) and Huffman and Duncan (24) kernels in corn silage of high dry matter content were harder and appeared more frequently in the cow feces than kernels in silage of lower dry matter content. Huffman and Duncan (24) noted no significant change in chemical composition of the corn grain as a result of passing through the digestive tract of dairy cows. Grinding of the HDMCS before ensiling reduced this problem in this experiment.

Production of 4% FCM per pound of dry matter consumed was nearly identical between treatments within trials. In Trial I, there were no differences in the production of 4% FCM per pound of dry matter consumed (0.96 lb of 4% FCM/lb of DM) between treatments. In Trial II the values were 0.87 pounds of 4% FCM per pound of dry matter consumed for MDMCS and 0.88 pounds of 4% FCM per pound of dry matter consumed for HDMCS. However, cows fed HDMCS gained more body weight 0.72 pounds vs. 0.88 pounds per day in Trial I, and significantly more in Trial II, 0.88 pounds per day vs. 1.63 pounds per day than cows fed the MDMCS. There was no significant difference in per cent milk fat or SNF between treatments within trials.

<u>Digestibility of the experimental forages</u>. A summary of the mean digestion coefficients determined simultaneously with feeding Trial II is given in Table 7. The coefficient of digestibility, using steers, of the dry matter was 66.9% for the MDMCS and 64.7% for the HDMCS (based on oven dry matter). The small difference in dry matter digestibilities may be due to the difference in stalk-leaf ratios of the two silages. Johnson et al. (27) reported greater cellulose digestibility for leaves when compared to stalks at four different

Table 7

Digestibility coefficients and digestible energy of the silages, Trial II

Corn silage	Digestion coefficients DM	Protein	Fiber	Energy	Digestible energy
	%				Kcal/g
MDMCS	66.9	54.7	66.0	66.7	2.75
HDMCS	64.7	51.1	64.4	65.4	2.72
Difference	2.2	3.6*	1.4	1.3	.03

*Statistically significant ($P < 0.05$).

stages of maturity (August - October). Since leaves made up the largest part of the field loss, this may have affected the digestibility of the total plant.

The coefficient of dry matter digestibility for the MDMCS is in agreement with the value (66.0%) obtained by Huffman and Duncan (25) in eight years of digestion trials and those obtained by Vander Noot et al. (42) for steers (64.42%). Byers and Ormiston (13) reported dry matter digestion coefficients of 62.7%, for silage containing 31.5% dry matter and 56.7% for silage containing 54.9% dry matter. The values reported by Gordon et al. (21) are higher for similar silages. The reason for this may be that Gordon et al. (21) used sheep to determine digestibilities of the silage. It has been reported (42) that sheep digest all nutrients, except nitrogen free-extract better than cattle in low protein, high carbohydrate feedstuffs.

The digestibility of the fiber was not significantly different between the two experimental silages. The lower digestibility of the fiber in HDMCS may be due to the higher stalk to leaf ratio and to the greater lignification of the more mature plants (27).

The coefficient of digestibility of the protein was significantly ($P < 0.05$) greater for the MDMCS (MDMCS 54.7% vs. HDMCS 51.1%). The significantly higher protein digestibility of the MDMCS may be due to the significantly higher crude protein content of the silages as fed. These values are in agreement with those reported by Bryant et al. (12) and Gordon et al. (21).

The gross energy in the MDMCS was slightly more digestible than that in HDMCS. The coefficients obtained were 66.7% for MDMCS and 65.4% for HDMCS, thus one gram of the MDMCS yielded 2.75 kcal of digestible energy while one gram of the HDMCS yielded 2.72 kcal of digestible energy. These values are somewhat lower than the values reported by Awoyemi (7) for a medium dry matter corn silage.

Digestible dry matter per acre from the MDMCS was 6577 pounds while that for HDMCS was 3411 pounds in Trial II. This means only 51.9% as much digestible dry matter was harvested per acre from the HDMCS when compared with MDMCS.

Expressing the feed value of the corn silage in terms of 4% FCM production per acre does not change the trend. Since the grain feeding was similar, an expression of milk production per pound of dry matter consumed can be used to estimate 4% FCM production per acre of crop harvested. One pound of dry matter was required to produce 0.87 lb of 4% FCM in the group receiving MDMCS and 0.88 lb of 4% FCM in the group fed HDMCS. Using these values, 8,553 lb of 4% FCM were produced per acre of MDMCS harvested while only 4,639 lb were obtained from the HDMCS. This represents a loss of 45.8% in 4% FCM returns per acre of corn silage when harvested as HDMCS. The per cent loss in digestible dry matter for HDMCS and 4% FCM per acre are nearly identical.

The amount of 4% FCM produced per pound of dry matter consumed was 0.87 for MDMCS and 0.88 for HDMCS. These data along with the small differences in digestion coefficients suggest that HDMCS can be used in emergency situations, but because of the larger field losses due to delayed harvest this should not be recommended as a general practice.

SUMMARY

Two feeding trials involving 20 cows each were used to compare the feeding value of high dry matter corn silage (HDMCS) with corn silage of medium dry matter content (MDMCS). A continuous feeding trial design was used in Trial I and a double-reversal design in Trial II. The HDMCS was ground with a hammermill using a 1.0 to 1.5 inch screen before ensiling. Both silages were stored in gas-tight units.

Significant differences associated with harvesting of HDMCS when compared to MDMCS include: 1) lower dry matter yields, 4.1% lower in Trial I and 44.2% lower in Trial II; 2) greater field dry matter losses, 17.6% compared to 6.9% for MDMCS in Trial I and 25.4% compared to 5.0% for MDMCS in Trial II; 3) higher percentage of ear loss, 6.6% before harvest in Trial I and 10.1% after harvest in Trial II; 4) lower carotene content; 5) lower total acid concentration during fermentation, 37.9% lower; and 6) a higher pH. No consistent trend in chemical composition of the silages between years was found.

Voluntary dry matter consumption was greater with HDMCS each trial and significantly greater during Trial II. The production of 4% FCM was significantly higher ($P < 0.01$) during Trial II for cows fed HDMCS. There was no difference in the per cent milk fat or SNF between treatments. The average body weight gain was greater for cows fed HDMCS, significantly ($P < 0.01$) greater during Trial II.

A digestion trial was conducted using four Holstein steers fed the experimental silages in three conventional total-collection digestion trials. The average digestion coefficients of the dry matter, energy, and protein for MDMCS and HDMCS were: 66.9, 64.7; 66.7, 65.4; and 54.7, 51.1, respectively. Only the digestibility of the crude protein was significantly lower ($P < 0.05$) for HDMCS. Using the digestible dry matter values as determined, an estimation of the pounds of digestible dry matter recovered per acre for MDMCS and HDMCS were 6577 lb and 3411 lb, respectively in Trial II.

Since one pound of dry matter was required to produce 0.87 lb of 4% FCM in the group receiving MDMCS and 0.88 lb of 4% FCM in the group receiving HDMCS, estimated pounds of 4% FCM productions per acre were 8553 lb for MDMCS and 4639 lb for HDMCS. These values are similar to the returns in pounds of digestible dry matter per acre.

Even though HDMCS is of equal feed value when compared to MDMCS, because of high field losses, delaying harvest of corn silage beyond a whole plant dry matter of 40% are not warranted.

CONCLUSIONS

The following conclusions were drawn from results obtained in this experiment:

(1) Delaying harvest of corn silage reduced dry matter yields and increased dry matter losses.

(2) The percentage of ears lost before and after harvest of HDMCS were greater than that of MDMCS.

(3) There was no consistent trend in chemical composition of the silages, however, crude fiber, ether extract, and ash were lower in HDMCS in both trials.

(4) Carotene content of HDMCS was lower than that of MDMCS.

(5) The total acid production during fermentation was lower for HDMCS, however, the lactic acid to total acid ratio was slightly higher for HDMCS.

(6) Total dry matter intake was greater for animals fed HDMCS.

(7) The average production of 4% FCM was greater for animals fed HDMCS in Trial II.

(8) The digestibility of crude protein of MDMCS was greater than that for HDMCS.

(9) The digestibility of the dry matter and energy was about equal for the two experimental silages.

(10) The pounds of digestible dry matter obtained and 4% FCM produced per acre were lower for the HDMCS.

(11) Because of greater field losses and lower returns per acre of crop harvested, general recommendations for harvesting corn silages of a high dry matter content is not warranted. However, this practice can be used in emergency situations as feeding value per pound of dry matter harvested is about equal to that of MDMCS.

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