THE EFFECT OF CORN SILAGE MATURITY, HARVESTING TECHNIQUES AND STORAGE FACTORS ON FERMENTATION PARAMETERS AND CATTLE PERFORMANCE

Thesis for the Degree of Ph. D.
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This is to certify that the

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Harvesting Techniques and Storage Factors on
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presented by

Mitchell Ray Geasler

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Animal Husbandry

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Date May 14, 1970

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ABSTRACT

THE EFFECT OF CORN SILAGE MATURITY, HARVESTING TECHNIQUES AND STORAGE FACTORS ON FERMENTATION PARAMETERS AND CATTLE PERFORMANCE

By

Mitchell Ray Geasler

Four experiments involving silo fermentation, animal performance and metabolic parameters in the ruminant were conducted to investigate their relationship to corn silage maturity, harvesting techniques and storage factors.

In the Fermentation Study, ten corn silage harvests were made at weekly intervals from September 3 to November 5 at dry matters which increased significantly ($P < .01$) from 22.1% to 48.3%. Each harvest was ensiled in four 12" x 18" stainless steel experimental silos within an airtight Plexiglas chamber. The chamber and/or silos were equipped with pressure application and measuring devices, temperature measuring mechanisms, total seepage collection and apparatus for taking daily samples from each unit. Four different pressures (0, 2.5, 5 and 10 psi) were maintained for a fermentation period of 12 days. As dry matter of the corn plant and/or maturity increased, lactic acid of the resulting silage was significantly reduced from a high of 5.8% to a low of 2.2% of DM ($p < .01$). Total nitrogen was significantly reduced from a high 1.3% of DM to a low of 1.1% of DM ($P < .01$). Water soluble nitrogen, expressed as a per cent of total nitrogen, dropped from a high of 32.2%

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to a low of 15.3%. Seepage decreased from a high of 16.90 ml./100 gm. of silage for the 22.1% DM silage to zero, irrespective of pressure, after the DM reached 34.7%. Pressure was apparently without effect on the end products of silage fermentation, as long as a minimum of 2.5 psi was applied. The pattern of fermentation during the 12 day period was not affected by maturity and/or dry matter content; however, extensiveness of fermentation was markedly affected.

In Feeding Trials 1 and 2, the effect of stage of maturity of corn silage on yield per acre was investigated. Fineness of chop was also studied relative to dry matter stored per cubic foot of silo capacity. Harvests made on September 13 (28.2% DM), October 17 (48.2% DM) and November 14 (59.6% DM), 1966 and September 18 (30.7% DM), October 5 (34.7% DM) and October 19 (43.3% DM), 1967 were compared. In both years a 40-acre field of "Michigan 400" corn was initially divided into eight-row plots. At each harvest date, two rows were harvested from each plot. The remaining two rows were picked to accurately determine grain yield per acre. In 1966, the 28.2% DM harvested silage yielded 5.11 tons of DM per acre, whereas the 48.2% DM silage yielded 4.57 tons per acre. This represented a reduction of 10.6%. The 59.6% DM silage yielded 4.06 tons per acre, a reduction of 20.5% from the 28.2% DM harvest, and a reduction of 11.0% from the 48.2% DM harvest. Dry matter yield per acre on the three dates in 1967 was 5.64, 5.86, and 5.56 tons, respectively, between the 30.7% DM harvest and the 34.7% DM harvest, a decrease of 1.41% between the first and the last harvest. Two identical silos were filled each year for each harvest date, one with fine chop silage (1/4 in.) and the other with medium chop silage (1/2 in. to 3/4 in.). Dry matter stored per cubic foot of sil

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foot of silo capacity in 1966 was 13.40 lb. vs. 11.14 lb.; 11.99 lb. vs. 9.96 lb.; and 11.93 lb. vs. 10.97 lb. for fine and medium chop in the 28.2% DM, 48.2% DM and 59.6% DM harvested silages, respectively. In 1967, dry matter stored in each silo was 12.32 lb. vs. 11.55 lb. and 13.15 lb. vs. 12.13 lb. per cubic foot of silo space for the 30.7% DM and 43.3% DM harvests, respectively. Combining fine and medium chop for each of the harvest dates in 1967, dry matter stored per cubic foot of silo capacity was 11.93 lb. vs. 12.64 lb. for the 30.7% DM and 43.3% DM harvests, respectively. In the fall of 1966, a 3 x 2 x 2 factorial experiment (12 lots of 9 head each) was initiated to study steer calf performance and carcass traits when fed the corn silage harvested in the fall of 1966. Cattle fed 28.2% harvested silage significantly ($P < .05$) outgained the 48.2% DM fed group (2.87 vs. 2.70 lb./day) and the 59.6% DM group (2.87 vs. 2.74 lb./day) but the 48.2% DM fed group was not significantly different from the 59.6% DM fed group. Carcasses from the 28.2% DM fed group were significantly superior to the 48.2% DM and 59.6% DM groups for all factors determining cutability. Pooled differences comparing fine and medium chop silage were small and insignificant; however, average daily gain values of 2.81 lb. for fine chop and 2.72 lb. for the medium chop silage approached significance ($P < .10$). Within harvest dates, average daily gain was 2.89 lb. vs. 2.85 lb.; 2.78 lb. vs. 2.63 lb. and 2.78 lb. vs. 2.69 lb for fine and medium chop silage harvested at 28.2% DM, 48.2% DM and 59.6% DM in September, October and November, respectively. For 48.2% DM and 59.6% DM harvested silages, both fine and medium chop were fed as ensiled vs. regrinding just prior to feeding. No difference in average daily gain (2.72 lb. vs. 2.73 lb.) resulted; however, pounds of feed consumed per 100 pounds of gain favored the reground fed group (7.14 lb. vs. 6.84 lb.).

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A 2 x 2 x 2 x 2 factorial experiment (16 lots of 8 head each) was employed in 1967-1968 to study steer calf performance and carcass traits when fed the corn silage harvested in the fall of 1967. Cattle fed the 30.7% DM harvested silage significantly ($P < .05$) outgained the group fed the 43.3% DM harvested silage (2.58 lb. vs. 2.46 lb.). This, coupled with a slightly lower daily dry matter consumption (17.27 lb. vs. 17.62 lb. DM intake), resulted in a substantially lower feed requirement per pound of gain (6.69 lb. vs. 7.16 lb. of 85% DM) in favor of the 30.7% DM silage fed group. Pooled results comparing the fine and medium chop silage showed no significant differences in animal performance. However, the cattle fed the fine chop silage produced significantly ($P < .05$) higher grading carcasses (high Good vs. middle Good).

The Metabolic Study was conducted in the fall of 1967 and involved eight fistulated wether lambs to test various metabolic parameters in a 2 x 2 (two stages of maturity x two degrees of chop) factorially designed study. The 30.7% DM harvested silage was consistently lower in dry matter and nitrogen digestibility, which resulted in a lower nitrogen retention. However, all values were nonsignificant. Stage of maturity had no effect on rumen volatile fatty acid production and voluntary feed intake. The lambs fed fine chopped silage had nonsignificantly greater rumen VFA levels compared with the medium chop silage fed group. Lambs fed the fine chop silage had a significantly ($P < .05$) higher voluntary feed intake than those fed the fine chop (819.73 vs. 583.15 gm./day). Dry matter digestibility, although nonsignificant, was lower for the fine chop silage (65.95% vs. 69.15%).

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A THESIS

Submitted to
Michigan State University
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for the degree of

DOCTOR OF PHILOSOPHY

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Member:

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I. INTRODUCTION

It has been theorized by most authorities on world population
d production that feeds having a high human caloric value and
n be consumed directly by the human population will play a
ole in ration formulation for meat animals by the year 2000.
ttle rank a poor third to broilers and swine in the efficiency
ersion of concentrate feeds. Thus, competition by these species
as the human population will force cattle feeders into nearly
e reliance on high yielding roughages and plant residues for
ng cattle.

Segregation of the total gross energy value of world food plants
ral, reveals almost as much gross energy in the stalk and leaf
as is contained in the grain or tuber portion. Therefore, it
that an ample supply of roughages in the form of crop residues
available for ruminant feeding in the future and that beef can
e to be a source of high quality nutrients in the human diet when
se residues.

Research conducted at Michigan State University and other research
has conclusively shown that silage is the best method for pre-
and storing the nutrients of the growing plant. In Michigan,
has further demonstrated that no other crop will equal corn silage
nergy production per acre of crop fed.

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Much research has been reported on the production and feeding of ilage; however, little is known relative to the effect of maturity, ss of chop and pressure on silage fermentation and cattle perform-

Therefore, the objectives of this study were:

(1) To more closely define the changes taking place in the silo fermentation and identify factors controlling these changes, thereby ishing criteria for constructing an efficient container for storing eserving silage.

(2) To evaluate the effect of stage of maturity and fineness of n yield per acre and silo storage capacity of corn silage when ted at various dry matter levels and/or stages of maturity.

(3) To evaluate the effect of fineness of chop and dry matter on in-silo fermentation, particularly in the production of organic and nitrogen fractionization in the silo.

(4) To test the effect of stage of maturity and fineness of chop ibolic parameters and feedlot performance of beef cattle when fed lage rations.

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II. LITERATURE REVIEW

The utilization of corn silage as an animal feed has been a well-
lished practice for some time. Coppock and Stone (1968) refer to
ngs dating back to 1852 which report research using corn silage in
e and England.

In 1877, Goffart, of Burtin, France, described in a practical way
nportant aspects of silage production. He discovered many important
tions necessary in preserving the corn plant properly. Specifically,
oposed reducing the length of cut from four centimeters to one centi-
and the application of a cover weighted with stones or brick to
the exclusion of air.

In a speech published in the official report of the State Board of
lture of Pennsylvania for the year 1888, John Stewart of Morganya,
lvania said, "The use of ensilage is no longer an experiment; the
s of its use in Ohio, New York, New Jersey and in our own state have
its value and its practicability." He went on to say, "The ensilage
d to be better for milk than hay, and the cows will milk nearly as
s when on grass. It costs us, by actual count, about fifty-nine cents
n. When we fed hay, each cow ate two tons in a winter, and with the
feed of meal, did not do nearly as well as with the ensilage, while
st of the daily food was eight times as much." In conclusion, he
"I will state that the man who builds and uses a silo will save

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-eighths of the cost of wintering his stock, and will keep them in as good order, and get as much milk, beef or butter from them. The ıas come to stay. Formerly I thought it the rich man's luxury, but see it is the poor man's necessity, and if I only had a farm of twenty I would have a silo and keep twenty cows the year through."

F. H. King, in 1900, wrote "Corn for silage--there is no crop now lly grown which is so well suited to the production of silage as corn, wherever it will grow well to maturity. The unavoidable with it are very small; heavy yield per acre may be secured with certainty at moderate cost; and the silage made from it has less ionable features than that of most other crops."

Silage production and preservation has progressed from this point any changes but with many questions left unanswered. It is the pur- f this review to examine the state of knowledge of silage fermentation thods of producing a quality product that will ultimately maximize performance.

Other reviews covering these as well as other subjects concerning are to be found in Watson and Nash (1960), Barnett (1954), Coppock ne (1968) and Owens (1968).

Fermentation

Watson and Nash (1960) define silage as "a succulent material pro- y a process of controlled vital changes from a green crop or other l of high moisture content. These changes which take place are mplex and depend on many factors." Thus, to identify these changes erstand how they come about, one must first describe the character corn plant and the resulting silage.

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In some very early work, Annett and Russel (1907) characterized
:n plant (green maize) and the resulting corn silage as shown in
.. From this analysis, they concluded that the major changes
:ook place during fermentation were a great reduction in nitrogen-
:tract (later found to be a breakdown of the soluble carbohydrate),
ease in nonprotein nitrogen (due to the breakdown of protein) and
st complete disappearance of the sugars. They also concluded that
rmentation does not affect the fiber content of the silage.

Benne _et al_. (1964) presents a very complete breakdown of the com-
of the corn plant and the content of each part including minerals.

The actual pattern of fermentation has best been described by
(1954) as a four-phase process.

Phase 1. A relatively short phase during which the plant cells
ll respiring. This results in the production of carbon dioxide,
lization of simple carbohydrates and a flow of water from the mass
these biological happenings and the mechanical compression of the
These events are accompanied by the evolution of heat.

Phase 2. A short time period in which small amounts of acetic
produced by coliform bacteria.

Phase 3. The point of initiation of the lactic acid fermentation
dependent upon the activity of lactic acid producing organisms,
illi and streptococci supported by adequate amounts of carbo-

Phase 4. The stage of quiescence in the mass during which the
cid production reaches its peak and remains at a high level. At
nt the pH should be less than 4.2. Condon _et al_. (1969) have
at this fermentation is complete at the end of eight days.

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TABLE 1

Annett and Russel - Silage Characterization

	Green Maize (%)	Maize Silage (%)
latter	16.81	12.99
Extract	0.48	0.39
.25	1.78	1.45
gen-free Extract	9.33	5.38
	4.21	4.82
	1.00	0.98
N	0.285	0.234
otein N	0.214	0.137
N (by difference)	0.071	0.103
ent of total N present as NPN	25.0	43.72
NH_3	----	0.007
Amide	----	0.006
s	1.10	nil
(as H_2SO_4)	----	0.09
latile Acids	----	0.49

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Peterson, Hastings and Fred (1925), while working with corn silage orted that the oxygen in the mass that is used in the production of the bon dioxide during Phase 1 had disappeared almost entirely within five rs. They showed that maximum concentration of carbon dioxide was ained at 46 hours. At this point, carbon dioxide comprises 60% to 70% the silo gases.

Russel (1907) held that there were three agents involved in the age-making process during Phase 1: (1) The living maize cell; (2) the nt enzymes; and (3) the microorganisms. He showed by the addition of iseptics to the mass that the first two were "primary and essential," the latter, the microorganisms, were only "secondary and nonessential." er works (Peterson, Hastings and Fred, 1925) showed that the bacteria e useful, if not necessary in the production of acids which drop the This work was done by sterilizing the mass to stop respiration, then oculating it with microorganisms.

The microorganisms in the silage are the chief agents in the protion of the alcohol and organic acids according to Peterson, Hastings Fred (1925). Kempton (1958) found that the initial number of bacteria the fresh crop bore no relationship to the final quality of the silage. also found that less than 0.1% of the bacteria on the crop at the time ensiling were capable of growing on lactobacillus selection medium.

Gibson, Sterling, Keddie and Rosenberger (1958) showed that the nant bacteria of fresh herbage disappeared rapidly. All typical ge bacteria proceeded to multiply immediately if they were represented he herbage and if the temperature was appropriate for the organism.

A complete review of the microbiology of silage is presented by ton (1958).

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Salsbury, Mather and Bender (1949) concluded that viability of
e culture did not follow pH of the silage during fermentation but much
re closely followed a simple linear decline with length of fermentation.

The temperature of the fermentation mass and its influence on
lage quality has been a question of great concern. Babcock and Russel
900) concluded that good silage could be made when the temperature
ver exceeded 24° to 26° C; this was in contrast to the concept that rela-
vely high temperature (55° C) for silage-making was not only inevitable
t beneficial (Coppock and Stone, 1968). Eckles (1916), among others,
owed that the greatest factor causing variation in silage temperature
s the amount of air incorporated in the mass. Furthermore, he con-
uded that good silage could be made at temperatures ranging from 10°
38° C. According to Watson and Nash (1960), the temperature of the
lage fermentation is wrongly thought by some to be the sole factor
ich controls the course of bacterial action. These authors also
ate that lactic acid producing organisms are most vigorous at 122° F
$^{\circ}$ C) and only killed at 167° F (75° C). Benne and Wacasey (1961) con-
ded that a temperature of 80° to 100° F is optimum for silage fermenta-
n. The work of Shaw _et al._ (1951) related silage pH to silage tem-
ature. In this work, silage pH did not go below 5.0 until the mass
ched 80° F. At temperatures above 100° F, the pH started to go up
in indicating an alteration in the fermentation.

McCullough (1969) reviewed work done at the Georgia station in
ch silage was harvested on days of various ambient temperatures. He
cluded that ambient temperature during harvest had no apparent effect
the final silage temperature. Forage ensiled on a hot day may have

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temperature greater than desired, but according to McCullough, it cools wn to a temperature determined largely by cell respiration.

The effect of high temperature (in excess of 60.5° C) was reported Bechtel, Atkinson and Hughes (1943). In this work they described what ey referred to as browning or darkening of the silage due to high temratures. Metabolic work with this silage showed that dry matter gestibility was reduced from 64% to 50%, protein digestibility was wered from 55% to 4% and nitrogen-free extract digestibility declined om 71% to 64% as a result of the high temperature. Also, the carotene lue of this silage was markedly decreased and the ash content increased. ese changes resulted in a decrease of 50% in consumption. Gordon 967) reported similar results when experimental silos were intentionally ated. Heating these silages after fermentation had little, if any, fect.

McCullough (1969) summarized the effect of temperature on silage mentation by characterizing three distinct types of silage.

(1) Seriously under-heated: This silage is usually a drab green or, has a strong odor, the tissues are slimy and have an insipid taste a pH of 5 or above.

(2) Properly heated: This silage is light green to yellow in r, has a pleasant vinegary odor, tissues are firm and it has a sharp taste indicative of a pH below 4.5.

(3) Overheated: These silages are from brown to black in color xhibit an odor from slightly burnt sugar to charred hay.

As stated previously, the temperature of the mass is closely d to the oxygen trapped in the mass. This, in turn, is almost a function of density of the silage mass, whether resulting from

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Kempton (1958)
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ıre externally applied or static pressure exerted from the weight e silage. Kearney and Kennedy (1962) concluded that air must be ded immediately. If not, a longer aerobic fermentation resulted here was a greater loss in soluble carbohydrate and lactic acid. rn, butyric acid production was increased.

Kempton (1958) also concluded that silage quality was determined rily by density or packing of the silage mass. Loosely packed silages eated and underwent primarily an acetic acid fermentation. Well-rved silages were firmly packed and contained as much as 150 micro- of lactic acid per gram of fresh weight. On the other hand, when e was packed too tightly, it contained only about 100 micromoles of te after two to three days in the silo, all of which subsequently peared, to be replaced by butyric acid.

The density of the silage mass and, in turn, pressures generated in lo, depend on weight of the silage mass which in turn is determined by ss of chop and dry matter content of the ensiled material, and height silage mass, all of which will be discussed later in this review.

Dexter, Huffman and Benne (1959) reported that pressures are vertical in a silo. (This is in comparison with water or any fluid h pressure at any one point is equal in all directions.) These also report that the pressure in a silo is equal to approximately ıd per square inch, per three foot depth, due to the weight of ge. In a 60-foot silo, this would equal 20 psi.

ı contrast, Yu, Boyd and Menear (1963) reported maximum pressure measured in a 30' x 60' upright silo was 700 psf, or approxi- psi. These authors also report that the pressure in a silo is ıfluenced by filling procedure.

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Murdock (1954)

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loss.

Boyd and Aldrich (1959) showed the effect of dry matter on pressure ing pure cellulose at various dry matter levels. When 100% dry matter, ellulose exerted 93.5 lb. pressure per cubic foot, when 95% dry matter, lb. per cubic foot, when 50% dry matter, 78 lb. per cubic foot and 25% dry matter, 70 lb. per cubic foot.

The losses encountered in silage production are also functions of ty and pressure. Losses are of two general types, fermentation and ge (Watson and Nash, 1968). The fermentation losses are influenced nsity, in that the greater exclusion of air, the less will be the loss; as, seepage losses are a function of pressure and dry matter content e ensiled material. King (1900) reported losses as a per cent of atter for various layers in the silo (Table 2).

Murdock (1954) reported seepage losses from concrete stave silos d from 40 gallons per ton of silage at 18% dry matter to no seepage when the silage reached 39% dry matter.

Miller and Clifton (1954) examined 24 tower silos filled with different forages involved in six different experiments ranging 12.2% to 38.6% dry matter. They concluded, as have all other workers, moisture content of the ensiled material was the primary factor iting seepage loss. These authors proposed the following prediction on:

$$\% \text{ DM lost} = 26.96 - 1.576 \text{ x} + 0.0230X^2$$

In this equation, X is the per cent of dry matter of the ensiled al. This model accounted for 84% of the variation in dry matter

Un

Layer
Surface
7th
6th
5th
4th
3rd
2nd
Bottom

TABLE 2

Unavoidable Losses in the Silo
(King, 1900)

yer	Pounds of Silage in Layer	% of Dry Matter Lost
face	8,934	32.53
th	8,722	23.38
th	14,661	10.25
th	48,801	2.10
th	13,347	7.01
rd	7,723	2.75
nd	12,689	3.53
tom	12,619	9.47

McCullough (1969
silage dry matter to si
ranging from 25% to 35%
It was hypothesized tha
the plant was below 25%
was above 35% dry matt
condition in the silo.

Huber, Thomas a
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McCullough (1969) reported some work conducted by Axellson relating age dry matter to silage pH, in which it was shown that dry matters ging from 25% to 35% produced the most suitable pH value (below 4.5). was hypothesized that pH was not reduced to the desired low level when plant was below 25% dry matter. The increase in pH when the silage above 35% dry matter was due to the inability to provide an anaerobic dition in the silo.

Huber, Thomas and Emery (1968) reported greater silo dry matter ses with 44% dry matter silage (15.1% loss) compared to 36% dry matter age (6.4% loss) and 30% dry matter silage (7.0% loss). In another dy, Goodrich et al. (1967) reported the opposite result, with greater mentation loss in a 32% dry matter silage than at 45% dry matter silage.

Nicholson and Cunningham (1964) added shredded newspaper to silage the expressed purpose of increasing the dry matter and compared this drying the material. They found that drying had less effect on organic d production.

McCullough (1969) states that "The dry matter content of a crop bably exerts no direct force on the events transpiring in the silo. importance stems from its usefulness as a relative measure of such ns as stage of maturity, protein content, and the relative difficulty packing the silage."

bohydrate Fermentation

The early work of Annett and Russel (1908) showed that the most king feature of silage fermentation was the breakdown of carbohydrates an increase in organic acids. Hunter (1921) proved that this breakdown due to bacterial action.

Johnson et al. (

hydrate levels in the c

This paper reported, as

soluble carbohydrate di

conclusively showed th

fresh, not oven-dried,

carbohydrate was destr

When studying t

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Johnson et al. (1966a) reported an extensive study of soluble carbo-
rate levels in the corn plant and its breakdown during fermentation.
s paper reported, as has earlier work, that a major portion of the
uble carbohydrate disappeared during ensiling. These workers also
clusively showed that carbohydrate determinations should be run on
sh, not oven-dried, samples. In their work, up to 60% of the soluble
bohydrate was destroyed during drying.

When studying the end products of silage fermentation (primarily
radation of carbohydrates to organic acids), it is necessary to divide
m into volatile and nonvolatile acids. Acetic acid is the primary
atile acid in silage fermentation with traces of propionic and butyric
d found in some silages (Barnett, 1954). However, lactic acid (the
or nonvolatile acid) is more important in silage fermentation and is
sent in larger amounts (Watson and Nash, 1960).

The work of Crasemann (1925), as reviewed by Watson and Nash (1960),
tes that 80% of the losses in silage are due to carbohydrate degradation.
semann (1928) also calculated the losses of energy due to the fermen-
ion of these sugars. He found that the conversion of sugar to alcohol
lts in a loss of 3.2%, whereas the conversion of sugar to acetic acid
resents a loss of 39.3% of the potential energy.

The breakdown of starch is not clear. Some work has shown that a
iderable amount is broken down (Dox and Yoder, 1920; Peterson, Hastings
Fred, 1925), while others show very little, if any, degradation
ter, Huffman and Benne, 1959).

Woodman and Amos (1924) reported that a portion of the fiber under-
breakdown as a result of bacterial activity with the probable forma-
of nitrogen-free extracts and organic acids. They also report that

the residual fiber has

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residual fiber has been shown to possess greater digestibility than original fiber of the green crop.

Many other compounds have been identified in silage as a result of fermentation. Morgan and Pereira identified many compounds by steam illing a silage sample. Among them were C_2 - C_6, isobutyric, α and methyldentyric acids, C_2 - C_6 aldehydes, 2 and 3 methybutanal, 2 methyl-nal, acetone, butanone, benyaldehyde, phenylacetaldehyde and furfural. many esters were found, but were not separated by the distillation.

The effect of the volatile fatty acids present in the silage on l performance has been shown by many workers. Conrad (1966), in a sium on voluntary feed intake, concluded that the acetic acid level lage reduces feed intake. Dinius, Hill and Noller (1968) added acetic to both green chop and corn silage at levels from 0% to 6% on a dry r basis. These animals voluntarily consumed up to 112.8 grams of te per 100 kg. of body weight. Thus, acetic acid additions did e dry matter intake, but had no significant effect on caloric intake. uthors concluded that "The animals in these trials were substituting y from acetate for energy from forage."

In contrast to these reports, Senel and Owen (1966), working with am silage, concluded that any depression in dry matter consumption feeding silages is due to something other than the acetate and lactate ibution of silages. In fact, a significant ($P < .01$) increase in atter intake was found when acetate was added at levels up to 2.8% e ration dry matter.

The lactic acid content of the silage has also been investigated sively. Klosterman et al. (1960) found that one pound of lactic acid in silage replaced

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Kempton (1958)

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in silage replaced 2.8 pounds of ration. From this, these workers luded that methods of ensiling or treatment of silage to increase ic acid content would be advantageous.

Kempton (1958) reports that lactic acid increased rapidly to a approaching 150 micromoles per gram of fresh material. Thereafter, was a relatively rapid decrease to an average of about 100 micromoles three weeks in the silo.

Schaadt and Johnson (1968) studied lactic acid in some detail in ed corn silage. They found that the production of lactate was com- by the end of eight days. The L(+) form of lactate was less ant than the D(-) isomer. This distribution of D and L forms did hange with fermentation time.

Lactate acts as a metabolic intermediate in the rumen. This was tigated by Hershberger _et al_. (1956). They found, in an _in vitro_ ntation using ovine rumen microorganisms, that lactate, along with ate, preferentially increased the rate of formation of acetic and onic acids, with lactate having the greatest effect on propionic In the same study, lactate decreased the rate of cellulose tion.

Prior to 1940, pH was considered to be the most accurate indicator lage quality. McLean (1941) analyzed many silages and concluded nany other measurements including dry matter were more accurate than

Watson and Nash (1960) state that "all the acids in silage ile, nonvolatile and amino) combine to give the total acidity of lage, an important value." They go on to report that it is not necessary to determine

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Protein Breakdown

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ssary to determine all the different acids since, in their estimation, s a satisfactory index of the course of the fermentation process.

ein Breakdown

The breakdown of proteins (proteolysis) is well established by authors. Watson and Nash (1960) state that it is now conclusive that breakdown is primarily an action of plant enzymes. Hunter (1921) showed that proteolysis is a result of plant enzymes in normal e. Russel (1908) found, as a result of an experiment with maize, the protein breakdown was due to the tryptic enzymes of the cell. n and Nash (1960) reported the work of Kirsch (1930), who treated lover silage in many ways including autoclaving a fresh sample to ensiling. This treatment destroyed the enzymes and, as a result, in breakdown did not occur.

The breakdown normally proceeds by way of relatively complex com- s to amino acids which can then be deaminated to form ammonia and complex volatile bases (Watson and Nash, 1960). Dexter, Huffman enne (1959) also report the formation of some longer chain acids as ult of this deamination. Russel (1907) reported many amines such ntamethylene diamine, betaine, adenine, and others.

The extent of proteolysis has varied greatly. Brody (1960) ted that in the silages he analyzed, up to 25% of the total nitrogen egraded to nonprotein nitrogen. Later work by Brody (1965) showed in hydrolysis ranges from 18% to 29% depending on the dry matter of nsiled material.

Corn Silage Maturity

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Silage Maturity

The research included in this review relative to maturity is being ned to work done with corn and, in a few cases, sorghum crops. No or alfalfa silage research is included because percentage of dry r was altered rather than maturity.

When reviewing the area of corn silage maturity, there is a great of confusion in terminology. Nevens, Harshbarger, Touchberry and n (1954), working with immature corn silages ranging from 15% to ry matter, classified the stage of maturity as follows:

	% Dry Matter
Ears beginning to form	15
Kernels forming	17
Early milk	20
Late milk	23
Early Dent	25
Well-dented	28
Kernels hardening, most leaves green	30
Kernels hardening, fewer leaves green	32

io workers (Johnson, 1967 and 1968) worked with silages ranging 0% to 71% dry matter and used the following terminology:

	% Dry Matter
Blister	20.2 to 21.3
Early milk	19.9 to 23.7
Milk-early dough	21.9 to 27.0
Dough-dent	27.2 to 28.6

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Stage of Maturity	%
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Milk	
Dough	
Glaze	
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	% Dry Matter
Glaze	33.5 to 34.6
Flint	38.4 to 47.2
Post-frost	46.7 to 50.8
Mature	71.0 to 71.7

Because of the variation in terminology, dry matter values will
ised in the review and research presentation rather than maturity
ns.

It has been shown that the physical stage of development of the
ı plant has a definite effect on the chemical and nutrient composition
the resulting silage. Hopper (1925) reported the proximate analysis
the plant, relative to maturity, as follows:

Stage of Maturity	% DM	NFE	CP	CF	Ash	E. Extract
Tassel	13.5	50.5	11.6	27.7	8.5	1.7
Milk	18.5	56.9	8.9	26.1	6.5	1.6
Dough	25.0	61.6	8.2	22.5	5.5	2.2
Glaze	32.7	62.2	8.3	21.4	5.4	2.6
Ripe	43.0	63.6	8.2	20.3	5.0	3.0

Other workers (Byers and Ormiston, 1966; Buck, Merrill, Coppock
Stone, 1968; Johnson et al., 1966; and Sprague and Leparulo, 1965)
ted a similar analysis, especially the reduction in crude protein.
er, the work of Owen and Webster (1958), working with sorghum silage,
ork reported by Colorado State University in 1959 show the reverse,
the more mature corn silage having a higher crude protein.

Johnson *et al*. (1

relative to dry matter

findings:

Per Cent Dry Matte

Whole Pla
13.8
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Johnson et al. (1963) analyzed the components of the corn plant ve to dry matter content as the plant matured and reported these gs:

er Cent Dry Matter of the Corn Plant and Components and % Ear

Whole Plant	Leaves	Stalks	Ears	% Ears
13.8	20.5	13.4	----	0
16.2	17.4	17.1	12.2	15
20.8	20.8	17.4	23.7	41
28.4	24.5	21.7	38.1	52
37.6	27.8	18.9	53.1	66
40.4	37.7	24.3	62.4	66

The reports relating corn silage maturity to dry matter yield are us. In general, they all conclude that dry matter yield is increased the stage of physiological maturity of the plant (Bryant et al., Nevens et al., 1954; and Owen, 1958 and 1962) and then decreases ler, 1969; Byers and Ormiston, 1964; Fowler et al., 1968; Gordon , 1966 and 1968; and Thomson and Rogers, 1968).

The most complete studies relating maturity and yield have been ted by the Ohio workers (Johnson et al., 1966 and 1968) and Huber, and Emery (1968). Johnson and McClure (1968) state that "the m yield of digestible energy per hectare would be achieved between ugh dent (28% DM) and the glaze (34% DM) stage of maturity." How- no actual data on yield were presented in this paper. In earlier Johnson et al. (1966), yield data were maximized when the dry content of the stalks, leaves and ears were approximately 20, 28 , respectively.

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In the Michigan State work of Huber, Thomas and Emery, silage harvested at 30%, 36% and 44% dry matter. At these dry matter els, the dry matter yields were 10.4, 12.2 and 10.2 metric tons per tare, respectively. This study supports the Iowa work (Hanway, 1963 1966) in that the plant actually stops accumulating dry matter at ıt 35% dry matter, which is referred to as physiological maturity.

In other studies, when dry matter levels were below 35%, the yield reased as much as 25% as it neared the 35% level. In studies working ı dry matter levels above 35%, losses were great. These reached levels 27% in some studies.

The effect of plant maturity on the fermentation in the silo is tioned by many authors. Huber, Graf and Engel (1965) reported that later harvested silage (51% dry matter, hard dough stage of maturity) a significantly higher pH than did silages harvested at 34% and at dry matter. Johnson and McClure (1968) found that very mature silage dry matter) had a pH of 7.7 after fermentation, indicating that little if any fermentation had occurred.

This fluctuation in pH is probably a reflection of the reduced production which occurs with dryer or more mature silages. Gordon, yshire and VanSoest (1968) reported higher amounts of organic acids he earlier harvested silages. They reported the levels of acetic, ionic, butyric and lactic acid to be 2.8%, 0.2%, 0.2% and 7.8%, ectively, when the silage was 32.4% dry matter, and 1.4%, 0.1%, 0.1% 3.7%, respectively, when the silage was 60.0% dry matter. Johnson l. (1965) and Klosterman (1963) reported about the same changes, as plant matured. In the paper by Klosterman (1963), lactic acid levels dropped from 11.33% c

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One factor thought to be directly related to the level of acid pro- ction in silage is the level of soluble carbohydrate in the plant when siled; this being the primary substrate for acid producing bacteria. nnson _et al_. (1966a) measured levels of carbohydrates and found that ey reached a peak when the plant was approximately 25% dry matter, d decreased linearly until the plant was mature. This reduction in luble carbohydrates followed virtually the identical pattern of organic d production in the resulting silage.

Johnson _et al_. (1967) reported an extensive study of the nitrogen tribution in silage and how this relates to maturity. These authors orted tungstic acid precipitable nitrogen as true protein and the gstic acid soluble nitrogen portion as nonprotein nitrogen. They also sured ammonia. They found the levels of ammonia and nonprotein rogen produced during fermentation to be lower as the plant matured increased in dry matter. This is another indication that the dry erial does not undergo as extensive a fermentation as does the more st silage.

Silo losses related to maturity are of two forms; seepage losses fermentation losses. Miller and Clifton (1965) reported that seepage ses approached zero as the ensiled material approached 30% to 32% dry ter. In a study reported by Sprague and Leparulo (1965), silages were at 24.3% and 32.5% dry matter. In this work, the early dent or ter silage resulted in a 5.6% dry matter loss during storage. The r harvested silage, 32.5% dry matter, resulted in 3.8% dry matter loss. silages above the 30% or 35% dry matter level, dry matter losses appear to be highest

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r to be highest for the higher dry matter silage. As mentioned pre-
ly, Huber, Thomas and Emery (1968) reported three dry matter levels;
36% and 44% dry matter. Silo losses realized at these dry matter
s were 7%, 6.4% and 15.1%, respectively. One could assume that the
er dry matter loss at the higher dry matter levels is due to increased
tion due to a decrease in compaction.

Coppock and Stone (1968) conclude that "dry matter losses resulting
bacterial fermentation may not reflect a net energetic loss because
ants can use the primary end products of the bacterial fermentation;
and lactic acids."

From this work, it has been concluded by Hoglund (1964) that silages
l be harvested between 32% and 35% dry matter to reduce total dry
losses during ensiling.

The effect of stage of maturity on the various digestibility values
rn silage have been investigated by many authors. Huffman and
(1960) reported the results of corn silage analysis over a 16-year
, and concluded that the average per cent of digestible dry matter of
ilage was 67.8%. In this same study, protein digestibility averaged

Probably the most extensive work relating corn silage maturity and
tter digestibility has been done by the Ohio group, Johnson *et al.*
and 1968). In this work, eight different silages were harvested
g from 20% dry matter to approximately 72% dry matter. Dry matter
ibilities were established using lambs. It was concluded that dry
digestibility increased from 66% to 72% as maturity increased up to
ugh dent stage of maturity, or approximately 28% dry matter. It
eveled off, with no significant difference from this point on. There
slight decrease after the 28% dry matter level. In other studies,

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gnificant increase in dry matter digestibility has been reported at matter levels above 28%. In the work of Thomson and Rogers (1968), gression equation is reported, relating dry matter digestibility and cent of dry matter of the corn crop. This regression equation is

$$\text{Per Cent dry matter digestibility} = 71.21 - 0.14X$$

is equation, X = dry matter of the crop being ensiled. Noller, er, Rumsey and Hill (1963) also report a regression equation to ate dry matter digestibility. Their equation is

$$Y = 70.88 + 0.06X$$

X being the number of days after the blister stage of maturity.

This would indicate that these workers agree with the Ohio work; dry matter digestibility does increase as maturity progresses, at to a point. Other workers have also investigated the effect of ity on dry matter digestibility (Bratzler, 1969; Buck et al., Byers and Ormiston, 1964; Caldwell and Perry, 1967; Hill and Noller, Kuhlman and Owen, 1962; Nevens, 1933; Noller, Warner, Rumsey and 1963; and Perry et al., 1968), and report varying results. From of these studies, Coppock and Stone (1968) concluded that the digest-y of the stalk and leaves of the corn plant decreases with maturity, at this decrease is compensated for by an increase in the proportion in in the total plant, so that the total dry matter digestibility plant is approximately constant throughout a range of 20% to 50% tter.

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The effect of maturity on crude protein digestibility has been
ted as varying in results. Gordon, Derbyshire and Humphrey (1966)
ted no difference in crude protein digestibility in the silages
were working with. However, Hunt and VanderNoot (1961) and Goering
. (1969) both reported that protein digestibilities were consistently
with higher dry matter silage, or later harvested silages. Related
is problem of protein digestibility is the report of Glover, Duthie
rench (1956), in which they concluded that the digestibility of crude
in was directly related to the per cent of crude protein of the
It was earlier shown in this review that crude protein in corn
es decreases with maturity and therefore, if this report is correct,
explain the decrease in protein digestibility previously reported.
report of Glover _et al_. (1956), the digestibility of crude protein
feed increased very rapidly at low protein levels from about 2%
crude protein. Thereafter, digestibility increases more slowly
de protein levels increase. This report concluded that the total
nt of crude protein in the feed, irrespective of its nature, deter-
the digestibility of the protein.

The work of Hunt and VanderNoot (1961), previously referred to,
oncluded that digestible energy increased with later harvested, or
dry matter, silages. This was one of the few papers reporting
ible energy.

The effect of maturity on dry matter intake has been reported by
uthors. Conrad, Pratt and Hibbs (1964) analyzed many different
s ranging from 52% to 80% digestibility. They concluded that the
s affecting intake, when a ration low in digestibility (52% to 66%)
ed, were such things as body weight, reflecting roughage capacity,

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undigested residue per unit of body weight per day, reflecting rate assage. When rations were fed that were high in digestibility (67%)%), the factors affecting intake were other parameters, such as oolic body size, production of the animal and digestibility of the on. Corn silages would fall in the high digestibility type of ration. efore, we must look for factors affecting intake which are not related e animal's capacity to consume more food.

Most authors have found that as dry matter increases, silage intake vise increases. Johnston and Cook (1970) reported a significant lation coefficient of 0.65 between dry matter of the silage and dry r intake. Again referring to the Ohio work of Johnson and McClure) and Klosterman et al. (1963), both reports indicate an increase in atter intake with increasing dry matter of the silage. However, the t of Klosterman et al. (1963) also states that the more mature silage tually poorer in feed efficiency. Noller, Warner, Rumsey and Hill) reported voluntary intake by heifers was 20% to 30% higher for the mature silages. Owen (1962) reporting on the work with sorghum es fed to lactating dairy cows, also reported an increase in consump- with the more mature sorghum silage.

In attempting to explain the increase in dry matter intake relative turity, Thomas, Moore, Okamoto and Sykes (1961) worked with alfalfa es and concluded that consumption was linearly and positively related matter content of the silage. However, this is a secondary rela- hip, since changing the dry matter content of the silage or hay at ng time did not alter consumption. Therefore, these authors con- d that the variation in dry matter intake was due to fermentation cts in the silage. There have been many other reports of dry matter intake increasing re

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ake increasing relative to maturity (Bryant et al., 1966; Bryant, er, and Blaser, 1965; Huber, Graff and Engel, 1965: Marshall, Nordon, s and Meyers, 1966; and Owen et al., 1967). In contrast, a report Goering et al. (1969) concludes that maturity had no effect on dry ter intake. In this study, silages ranging from 23% to 47.8% dry matter used.

There were no reports of the affect of corn silage maturity on n parameters. However, Mahopatro and Leffel (1964), working with lfa and sudex silages at various dry matter levels, reported that cent of rumen acetate was lower and per cent of propionate and buty- were higher when either hay or dry silages were fed.

The majority of the work relating corn silage maturity to animal ormance has been done with lactating dairy cows. The reports by s and Ormiston (1964), Gordon, Derbyshire and Humphrey (1966), Gordon, yshire and VanSoest (1968), Marshall et al. (1966) and White and son (1929) all showed no increase in milk production related to rity of the corn plant. Huber, Graff and Engel (1965) reported a ficant increase in milk production as maturity increased, but con- d that this was due to an increase in dry matter intake, and that lly there was no effect on the efficiency of milk production. Later, , Thomas and Emery (1968) reported milk yields were decreased with asing maturity of silage.

Reports of feeding trials with growing animals are not so numerous e work with lactating dairy cows. However, a considerable number of rs have reported results using various corn silage maturities. In of these reports, the silage has constituted a larger portion of ation than is the case with the lactating cow. Therefore, these

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ials are a more direct evaluation of the silage being fed but yet are nfounded with a difference in dry matter intake. In one study, by ller, Warner, Rumsey and Hill (1963), heifers were used in a comparison green chop corn with corn silage. In this report, the heifers gained gnificantly faster (1.66 lb./day) on the green chop material in compari- with the corn silage (1.10 lb./day). Zimmerman, Newmann, Hinds and ib (1965) reported three moisture levels of corn silage; 72.7%, 66.4%, 59.7%. In this study, the average daily gains reported were 2.16 lb., 5 lb., and 2.17 lb. per day, respectively, with 2.35 lb. being a nificantly faster gain than the other two. Feed efficiency was 7.31, 1 and 7.78 for the three moisture levels, respectively. Burroughs and el (1969) reported work at Iowa State University using 32% and 44% dry ter silage. They found no difference in average daily gain when the ages were fed to beef steers. However, feed efficiency was better for wet silage, and the wetter silage produced greater returns. Feed version was expressed as net energy for maintenance plus gain per nd of gain in megacalories. These values were 6.65 for the wet silage % dry matter), and 6.48 for the dry silage (44% dry matter). In ther study at Iowa State University, Fowler et al. (1968) reported ter feed conversion for a 32% dry matter silage. However, because of ner feed intakes, the 45% dry matter silage showed a higher rate of n, higher dressing percentage, higher carcass grade and therefore a higher return per acre. The Minnesota group (Goodrich et al., 1967) found no nificant difference in daily gain when silages were fed at 32% versus or 45% dry matter. Likewise, Klosterman et al. (1963) reported no ificant difference in average daily gain. In later work, Klosterman 4) reported heifers gained slightly faster with slightly better feed efficiency when fed

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iciency when fed a 41.4% dry matter silage compared with a 37.7% dry ter silage. This difference was attributed to an increased feed intake. ry, Mohler, and Beeson (1961) reported on two extremely short feeding als comparing silages of 29.7% dry matter and 37.0% dry matter. There e consistent differences in average daily gain and feed efficiency in s trial favoring the 29.7% dry matter silage; however, no statistical ysis was reported.

There have been many questions relative to the amount of energy due to passage of kernels in the feces. Huffman and Duncan (1959) rted that an average of only 2.7% of the whole kernel dry weight umed in corn silage was voided in the feces of lactating cows. This true when silage averaged from 26% to 28% dry matter. In a trial rted by Buck et al. (1969) relating kernel passage to silage dry mat- there was very little difference found. When working with silage 5% dry matter, relative to 40% dry matter, the average sieve size in imeters was 0.676 compared with 0.634 for the two dry matter levels, ectively. Therefore, it could be concluded, as did Coppock and Stone 3), that the loss in passage of whole kernels when cattle are fed silage, is of relatively little importance.

Many authors have summarized the effect of maturity of corn silage ie various parameters already reviewed. Owens, Jorgensen and Voelker) summarized their work by stating that harvesting at high dry rs (62% dry matter) instead of at medium dry matters (39% dry matter) cause the following changes: (1) a lower dry matter yield; (2) er field dry matter loss; (3) higher per cent of ear loss; (4) lower ene content; (5) lower total acid concentration during fermentation % vs. 5.47% of dry matter); (6) higher pH (3.88 vs. 4.18). In this trial also, voluntary

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al also, voluntary dry matter consumption, milk production and weight ns were in favor of the higher dry matter silage. Nevens and Duncan 42) recommended that silage be harvested at 30% dry matter. Their k indicates that at this stage of maturity, when the entire plant is dry matter, the ears will range between 40% and 50% dry matter and stalks only 20% dry matter. The Illinois work also showed the best ication of maturity, as far as a measurement for accurately determining urity, is the dry matter of the leaf portion of the plant, as reported Nevens and Duncan (1949). This is particularly true when the dry ter is below 35%. When above 35%, the leaves dry rapidly and leaf dry ter is not a good indication of plant dry matter. Gordon (1967) con- led that "the optimum harvest stage for corn as judged by yield and ding value coincides with lower moisture contents."

The review by Coppock and Stone (1968), reports that the effect of reasing maturity of the corn plant from 20% to 35% dry matter results 1) a decrease of green forage, but a significant increase in dry forage d; (2) probably a small increase in harvest loss; (3) a significant ease in storage losses; (4) no consistent effect on digestibility of resulting silage dry matter; and (5) an increase in the voluntary ke of silage dry matter. Allowing the plant to mature beyond 35% dry er will result in (1) little gain in dry matter production; (2) a ificant increase in field losses; (3) the possibility of greater storage es in conventional tower and horizontal silos; (4) no consistent effect igestibility of the resulting silage dry matter; and (5) an increase in voluntary intake of silage dry matter.

The effect of fineness of chop on silage parameters and animal per- ance has been studied by very few authors. Many have speculated as to this effect. For in

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effect. For instance, Benne and Wacasey (1961) stated that proper
ing depends upon moisture content of the crop and how finely it is
ped, but they cite no particular experiments. In reference to meta-
c parameters and actual animal performance, the most extensive work
his area has been done by the Virginia group. Two different reports,
of Huber, Sandy, Miller and Poland (1966) and that of Miller, Poland,
y and Huber (1968), review this work. In the 1968 report by Miller
l., three silages of 44% dry matter were utilized. The first was a
al field chop silage. The second treatment was grinding the ears and
mixing them with regular field chop stalks. In the third treatment,
entire plant was rechopped. All treatments were made prior to ensiling.
metabolic study indicated digestibility of the dry matter and nitrogen-
extracts was higher on treatments two and three. Crude protein
stibility was highest on treatment three, and crude fiber digestibility
highest on treatment one. Dry matter intake values were 2.2, 1.9 and
kilograms per hundred kilograms of body weight for the three treatments,
ectively. In the milking trial, fat corrected milk (FCM) was 28.0,
and 26.3 kilograms per day for the three treatments, respectively,
a milk fat test of 86%, 75.8% and 81.1% compared to the standardiza-
period (100%). The low values for treatments two and three in milk
ere attributed to a low acetate to propionate ratio. In the earlier
reported by Huber et al. (1966) a similar milk fat depression was
ted. This earlier work also reported no difference in average daily
when growing dairy heifers were fed the silages. However, this study
d with Miller et al. (1968) on differences in digestibility coefficients.

In another study, Buck et al. (1969) reported the effect of recutting
rnel passage and feeding value of corn silage. In this work, recutting

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plant before ensiling reduced the amount of kernel dry matter in the es but had no significant effect on the total digestible nutrients or estible energy values of the silages. In this study, Buck used silages er in dry matter than those used in the work of Huber and Miller, and may account for some of the differences he reported. Kolari et al. 58) reported no differences in cattle performance when silage was made the flail chopper as compared with a regular chop. In this work, flail chopper was hypothesized to affect cattle performance because would break all kernels. This was found not to be true in that study.

ary

In summary, most authors agree that the most effective stage of rity to harvest corn silage to optimize all factors is somewhere in range of 30% to 35% dry matter; or, using the terminology of the Ohio ers, this would be in the dent to glaze stage of maturity.

There has been very little work completed to establish the effect ineness of chop. However, many authors have eluded to this and coned that a fine chop is desirable, if not necessary.

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III. MATERIALS AND METHODS

A series of four different experiments--a fermentation study, feeding trials, and a metabolic study--is included in this dis-
:ation. Materials and methods are presented under experimental
lings. All silages used were characterized by the methods described
:xperiment 1.

Experiment 1 - Silage Fermentation Study

Design. A 10 x 4 factorial design was utilized to study corn
ge harvested at ten harvest dates and ensiled under four pressures.
est began on August 27, 1969 and terminated November 5, 1969. Silo
sures were 0, 2.5, 5.0 and 10.0 pounds per square inch (psi).

Experimental silos used in this study and shown in Figure 1 were
gned by the author and constructed with 3/16-inch stainless steel to
stand an internal pressure of 25 psi. Silos measured 12 inches in
eter by 18 inches high (1.39 cubic feet). A series of 3/32-inch holes
drilled in the bottom and on opposite sides of the silo to allow
ient to escape from the silage mass. A stainless steel funnel was
d in place beneath the bottom of the silo and connected by stainless
tubing to the series of holes on each side of the silo for collecting
ent. Silo pressure was applied by using a three-ton hydrolic jack
ted between a stainless steel floating plate and a rigid steel struc-
velded to the sides of the silo and extending over the top.

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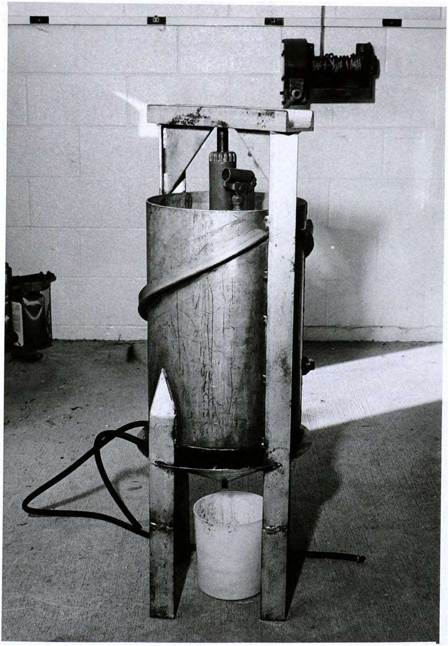
FIGURE 1

Experimental Silo Unit



This stainless steel cylinder was used as the silo unit in the mentation study. It was equipped with pressure application and measng equipment, a seepage collection system and a temperature thermister follow silage mass temperature.

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Silo pressures were measured with a pressure cell constructed of Plexiglas and shown in Figure 2. Pressure cells were fabricated locally in accordance with the design of J. Boyd, Michigan State University Professor of Agricultural Engineering. A pressure cell was inserted in the bottom of each miniature silo. Pressures were measured as follows:

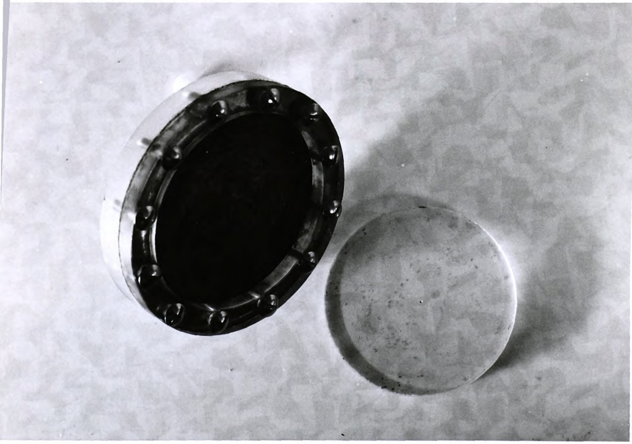
Air was pumped into the external chambers of the pressure cell. When pressure within the chamber equaled or slightly exceeded the pressure exerted by the silage mass upon the chamber, the diaphragm covering the chamber would be raised and air allowed to escape through the center of the pressure cell forming a bubble in a water vessel at the end of the escape hose. The apparatus gave rough estimates of pressure in each cylinder, but was not accurate enough to determine exact pressures being applied.

Seepage was collected in a two-liter plastic cylinder placed beneath the collection funnel in each silo. At each harvest, four silos were filled with the same corn plant material. Three of the silos were constructed as described. The fourth was a heavy plastic five-gallon carboy with a 3/16-inch Plexiglas plate as a cover which was used as the zero pressure silo. Each silo was equipped with a temperature measuring thermister connected to a temperature measuring gauge. Temperatures were recorded at the time of filling, and at 24 hour intervals thereafter.

Four silos were filled at each harvest. All four were placed in a Plexiglas chamber (see Figure 3). The chamber was four feet square and five feet high and equipped with six black plastic surgical gloves. It had a 12-inch cube port for entry and removal of samples during the

FIGURE 2

Pressure Measuring Cell



This Plexiglas cell was constructed to measure pressure in the silo unit. It laid flush to the bottom of the silo.

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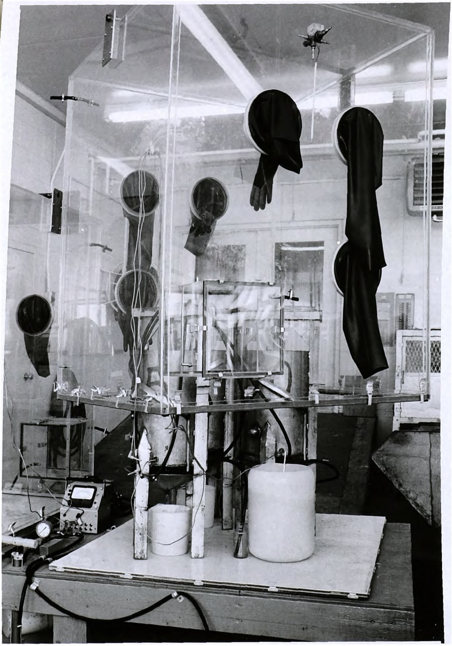
FIGURE 3

The Silo Chambers



Silo units representing the four pressure levels were placed in a x 4' Plexiglas chamber which was infused with CO_2 to maintain anaerobic ditions. The temperature measurement unit can be seen between the two mbers.

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:ermentation period. The chamber was infused with carbon dioxide (CO_2) ;o as to maintain an anaerobic atmosphere.

Silage. The silage used in this study was harvested from a plot f "Michigan 400" corn maintained specifically for this use. At each arvest date, two rows were chopped with a Fox self-propelled chopper nd brought directly to the Beef Cattle Research Center. The silos were illed and placed in the chamber as soon as physically possible (varied from vo to six hours) after chopping the corn plant. Uniformity of fineness of iop was maintained by the use of a recutter screen inserted in the iopper throughout the ten harvests. The silage from each harvest was lowed 12 days of fermentation in the silo. At the end of the 12-day riod, the apparatus was dismantled, and the silos were unloaded and made ady for the next harvest which started two days later. By utilizing ch a time schedule, the 10 harvests which were made weekly were run two sets of the miniature silos and anaerobic chambers.

Sampling and Data Collection. The weight of the ingoing silage ; recorded as the silos were being filled at each harvest. The same ocedure was followed when emptying each silo. Two samples of the ingoing age were taken; one for oven dry matter determination, and another to frozen for later analysis. However, two to six hours had lapsed between pping and sampling.

During the 12-day fermentation period, data were recorded daily for page volume, and temperature of the silage mass. A silage sample was o taken daily from the top of each silo by removing the pressure jack floating plate. Pressure was reapplied after taking the sample. ige samples were passed out of the chamber through the port so as to

maintain an anaerobic atmosphere (see Figures 4 and 5). At the end of the 12-day fermentation period, each silo was unloaded and the contents sampled. All samples were frozen for later analysis.

Silage Analysis. A schematic diagram of analysis conducted is shown in Figure 6. Immediately after thawing the silage samples, total nitrogen was determined by macro-Kjeldahl procedures and per cent dry matter determined by oven drying for 24 hours at 55° C. (See Appendix V for verification of this method.)

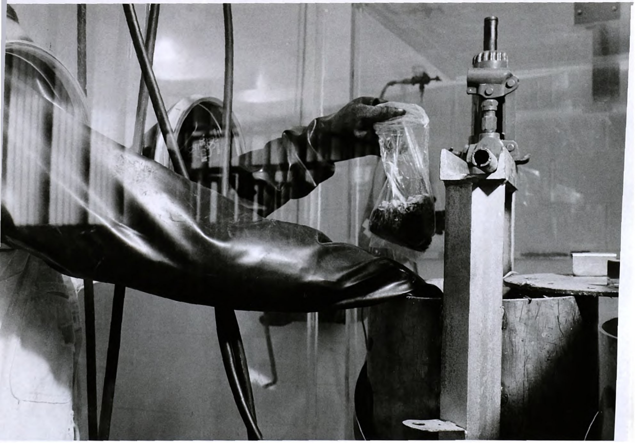
Silage extracts were prepared by homogenizing a 25 gram aliquot of the sample in an Lourdes homogenizer with 100 ml of distilled and deionized water for one minute and straining through two layers of cheesecloth. A 0 ml aliquot of the extract was used for determining pH and soluble nitrogen. pH was determined on a Corning Model 12 pH meter and soluble nitrogen was determined by micro-Kjeldahl procedures.

The remainder of the extract was deproteinized using one ml of 50% sulfosalicylic acid (SSA) and nine ml of extract. The sample was then centrifuged at 18,000 rpm for 10 minutes and stored in a refrigerator for later analysis. Volatile fatty acid content of the silage was determined by injecting samples of the deproteinized silage fluid described above into a Packard gas chromatograph. Colormetric procedures of Barber and Summerson (1941) were used to determine lactic acid content of the deproteinized sample.

Soluble carbohydrate determinations were made using the deproteinized extract according to the procedure of Johnson *et al*. (1966), but modified slightly. In the modified procedure, the same volumes as called for by Johnson *et al*. were used, but instead of allowing the particles to settle, they were spun in a centrifuge at 10,000 rpm for five minutes before

FIGURE 4

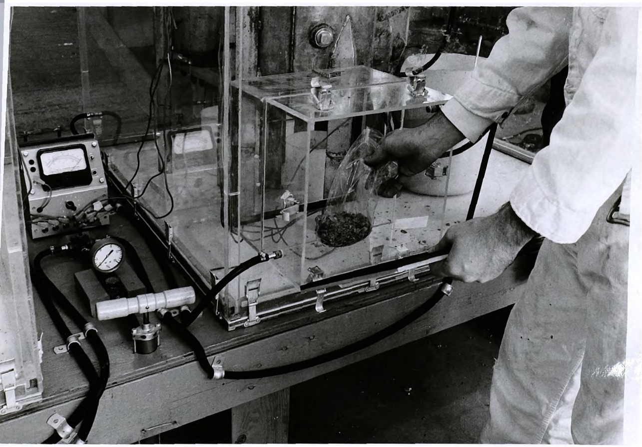
Sampling Procedure



Samples were removed from the top of each silo unit daily. This
as done by removing the floating plate and jack to get to the silage mass.
fter the sample was taken, the pressure was reapplied.

FIGURE 5

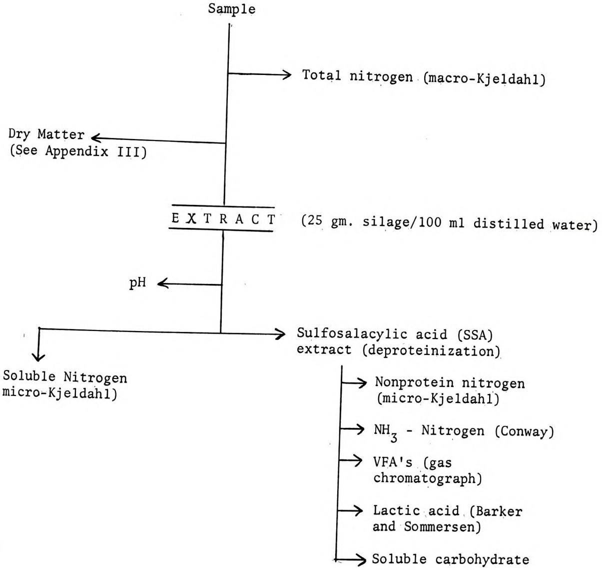
Sample Removal from the Chamber



The daily samples were removed through this one cubic foot port. The port was flushed thoroughly with CO_2 prior to opening it into the chamber each day.

FIGURE 6

Schematic Diagram of Laboratory Analysis
Conducted on Silage Samples



ıking an aliquot of the supernatant for carbohydrate determination. This ɘmoved all starch particles which might have remained in the soluble raction. This resulted in an analysis of only the actual soluble carbo-ydrate portion of the corn plant. Results, using this modified procedure, ere very similar to the Johnson et al. data; however, values were much ower.

Nitrogen fractionization of the silage was done as follows: (1) otal nitrogen was determined on the freshly thawed silage sample by macro-jeldahl procedures; (2) Total soluble nitrogen was determined on the ater extract of the sample before deproteinization by micro-Kjeldahl rocedures; (3) Using the deproteinized extract, total water soluble onprotein nitrogen was determined by micro-Kjeldahl procedures; (4) The ifference between water soluble nitrogen and water soluble nonprotein itrogen was called water soluble protein; and (5) Ammonia nitrogen in ne water soluble nonprotein nitrogen fraction was determined by the ethod of Conway (1950).

Experiment 2 - Feeding Trial 1

The experimental design of this trial was a 3 x 2 x 2 factorial, ilizing 12 lots of steers with 9 head per lot, a total of 108 steers. eatments started were: Three harvest dates, two degrees of chop at rvest, and two degrees of regrinding at feeding time.

Harvesting of Silage. Corn silage ("Michigan 400") was harvested September 18, October 17, and November 14, 1966. Two silos were filled each harvest date; one with a fine chop silage (3/8-inch) and one with medium chop silage (1/2-inch to 3/4-inch). The corn field was divided o eight-row plots. Two rows of each plot were harvested in September,

vo in October, two in November, and two were harvested as ear corn mmediately following the November harvest to establish grain yield per cre.

The September and October harvests were ensiled in four 16' x 50' oncrete stave silos, and the November harvest was stored in two 12' x 50' oncrete stave silos. No additives were applied to the silage.

Each load of silage was sampled for per cent dry matter during arvest to compute yield per acre and silo storage capacity.

October and November harvested silage, both fine and medium chop, ere fed "reground" and "as ensiled." Regrinding was done by running the ilage through a hammer mill immediately after removing it from the silo nd just prior to each feeding. Thus, physical form of the reground fine nd medium chopped silages was the same, which provided an opportunity to etermine if cattle performance differences were due to physical form or o a difference in silo fermentation. The September silage was not eground because its high moisture level caused difficulty in grinding.

Feeding Trial. Choice Hereford steer calves, averaging 475 pounds ien purchased in mid-October, 1966, were acclimated on a ration of corn lage and protein before use on this trial. They were put on experiment nuary 13, 1967 at an average weight of 538 pounds.

The cattle were randomly assigned by weight to 12 lots of 9 head ch, and treatment combinations were assigned at random (see Appendix II).

All steers were weighed on two consecutive days and the average of e two weights was used as the initial and final weight on the experiment. ey were assigned blocks on the basis of their first-day weight and ran- nly assigned pens from each block following the second-day weight.

All lots of cattle were fed twice daily a ration comprised of a full feed of the appropriate corn silage, 1% of body weight daily in rolled shelled corn, (adjusted every four weeks according to the average lot weight) and one pound of MSU-64 supplement per head daily (see Table 3). All ration ingredients were combined in a horizontal mixer and thoroughly mixed prior to each feeding.

No vitamin A was included in the supplement since all cattle were used in another study which evaluated methods and potency of injectable vitamin A on a within-lot basis.

All cattle remained on feed for 180 days and were slaughtered on July 12, 1967 at an average weight of 1,036 pounds. Following slaughter, the carcasses were allowed to hang in the cooler for 48 hours, were graded by a Federal grader, and tracings made of the 13th rib. All estimates of carcass quality and desirability were made by a Federal grader.

Shrinkage to market averaged 2.43% for all cattle, computed after a 100-mile haul using slaughter weights over off-experiment weights. Dressing percentage values were computed by using cold carcass weight over off-experiment weight.

During the course of the experiment, all silage refused by the cattle was removed from the bunk and reweighed. Because of the degree of chop treatment, this was necessary to get a true evaluation of feed efficiency. The amount refused by each lot of cattle can be determined by subtracting the amount of corn silage consumed from the amount fed as listed in the animal performance data.

TABLE 3

MSU 64% Supplement Formula

Ingredient	Pounds Per 1,000 Pound Mix	One Pound Daily Provides
45% Feed Grade Urea	130.0	0.64 lb. Protein
50% Soybean Oil Meal	538.2	
Ground Shelled Corn	115.0	
Dicalcium Phosphate (26.5% Ca. - 20.5% P)	100.0	12 gm. Ca. - 9 gm. P
Trace Mineral Salt	100.0	1.6 oz.
Sodium Sulfate (22.5% S)	8.1	800 mg.
Aueromycin (50 gm./lb.)	1.5	75 mg.
Vitamin D (9,000 IU/gm.)	2.2	9,000 IU
Stilbestrol Premix (2 gm./lb.)	5.0	10 mg.

(Not more than 37% protein equivalent derived from Urea)

Experiment 3 - Feeding Trial 2

A 2 x 2 x 2 x 2 factorial design was utilized (16 lots of 8 head each) to study two harvest dates, two degrees of chop, two concentrate levels and two replications.

This experiment differed from Experiment 2 - Feeding Trial 1 in that two concentrate levels were fed. One-half of the cattle received a ration made up entirely of corn silage and supplement and the other group received a full feed of corn silage plus 1% of body weight daily in shelled corn and supplement. Differences in concentrate level were included in this experiment to investigate the possibilities of an interaction between corn silage maturity, fineness of chop and concentrate level. Data from this portion of the experiment are not presented since no interactions were found.

Harvesting of silages. As in Experiment 2 - Feeding Trial 1, the field of "Michigan 400" corn was divided into eight-row plots with two rows harvested on September 18 (30.7% dry matter), two rows on October 3 (34.7% dry matter), and two rows on October 19, 1967 (43.3% dry matter). The October 3 harvest was made by the Dairy Department and only yield data are presented. To establish grain yields per acre, the remaining two rows of the eight-row plot were harvested in mid-November as ear corn.

For the September 18 and October 19 harvest dates, two silos were filled; one with a fine chop (3/8-inch) and one with a medium chop (1/2-inch to 3/4-inch) silage. The silage was ensiled in four 16' x 50' concrete stave silos with metal roofs; four of the same silos used in Experiment 1. No additives were used in any of the silages. As in Experiment 1, each load of silage was weighed and sampled for dry matter determinations. Fermentation of silage took place for a minimum of 30 days before being fed.

Feeding Trial. Choice Hereford steer calves, averaging 460 pounds when purchased in mid-October, 1967 were used in this trial. The steers were fed a ration of corn silage and one pound of MSU-64 supplement per head daily for 30 days prior to being placed on trial November 17, 1967, weighing 478 pounds. All cattle were implanted with 24 milligrams per head of stilbestrol on December 13, 1967 and reimplanted with 36 milli- grams per head on April 6, 1968. They were weighed on two consecutive days and the average of the two weights was used as the initial and final weight. The steers were assigned to blocks on the basis of their first-day weight and randomly assigned to the respective treatment combination following the second-day weight.

All lots were fed a completely mixed ration twice daily of the appropriate corn silage, MSU-64-67 protein supplement (one pound per head per day--see Table 4) and the appropriate level of concentrate.

Four cattle in each lot receiving 0% concentrates (representing the weight range in each lot) were terminated when the average weight of all cattle reached approximately 1,025 pounds. The remaining four cattle were left on feed to be terminated when they reached 1,150 pounds. The same procedure was followed for terminating the lots receiving 1% concen- trates. Immediately following the final weight, all cattle were trucked [illegible] miles to a commercial slaughtering plant, were allowed to stand over- night and were slaughtered during the morning of the next day. Following slaughter, the carcasses were allowed to hang in a cooler for 48 hours before measurements were taken. Loineye and fat tracings were made of the [illegible] rib. All estimates of carcass quality and desirability were made by [illegible] federal grader.

TABLE 4

MSU 64-67 Supplement Formula

Ingredient	Pounds Per One Ton Mix	One Pound Daily Supplies
45% Feed Grade Urea	230	0.32 lb. Protein
50% Soybean Oil Meal	1,259	0.32 lb. Protein
Cane Molasses	50	Binder
Dicalcium Phosphate (26.5% Ca. - 20.5% P)	200	12 gm. Ca. - 9 gm. P
Trace Mineral Salt (High Zn.)	200	50 gm. Salt
Sodium Sulfate (22.5% S)	40.4	2.06 gm. S*
Aureomycin (50 gm./lb.)	3.0	75 mg.
Vitamin A (10,000 IU/gm.)	13.2	30,000 IU
Vitamin D (9,000 IU/gm.)	4.4	9,000 IU

*Ratio of 1 part S to 11.3 parts N in urea or 1 part S to 22.6 parts N in supplement.

Shrinkage to market averaged 2.2% for all cattle, calculated by using weights taken after the 100-mile haul over off-experiment weights. Dressing percentage was computed as in Trial 1.

Experiment 4 - Metabolic Study

Design. A 2 x 2 replicated factorial design was utilized to study two silage maturities and two degrees of chop (see Appendix II). Silages studied were the same as those utilized and described for Experiment 3 - Feeding Trial 2. The trial was conducted concurrently with Experiment 3 - Feeding Trial 2 and was initiated on March 16, 1968 and completed on March 23, 1968.

Eight mature Cheviot wethers (one year of age) fitted with rumen canulae (Jarrett, 1948) and averaging 31.3 kg. at the start of the trial were utilized to study metabolic parameters of the respective silages. The sheep were fed the respective silage for two weeks in 4' x 4' individual pens before being placed in a collection crate for one week. After the sheep had been in the collection crate for one day; feed intake, water intake, urine and fecal output were measured and sampled for analysis over a six-day period. On the seventh day, while the animals were still in the collection crate, rumen samples were taken just prior to feeding and at two, four and six hours postfeeding.

Feeding Regime. The sheep were fed twice daily, at 8:00 a.m. and 5:00 p.m. in amounts which assured *ad libitum* intakes. The ration was composed of the respective corn silage which was removed from the silo just prior to each feeding plus a mineral supplement added at 3% of the silage dry matter. The silage was weighed and thoroughly mixed with the mineral supplement prior to each feeding. After all ration ingredients were

mixed, samples were taken for laboratory analysis and dry matter determination. Unconsumed feed was weighed, sampled and discarded before the 8:00 a.m. feeding each day. Water was provided ad libitum throughout the trial.

Sample Collection. Total fecal collections were made by fitting each sheep with a heavy plastic bag cemented to the posterior of the sheep. 'eces was removed on a daily basis and weighed. Two per cent was retained or dry matter determinations and frozen for later analysis.

Total urine was collected in a two-liter glass bottle which conained 25 ml of 20% sulfuric acid and one ml of 10% copper sulphate. The otal volume was measured and then diluted with water up to 1,800 ml. ne-sixth of the diluted urine from each of the six days' collections was etained for later analysis.

The pH of the rumen samples was determined with a Corning Model 12 meter, and whole rumen contents were strained through two layers of eesecloth to which one ml of saturated mercuric chloride was added per ml of the strained rumen fluid. This mixture was retained for volatile tty acid and rumen ammonia analysis.

Laboratory Analysis. Dry matter of feed presented, the consumed d, and feces was determined by drying the sample at 105° C for 24 hours e Appendix V). Silage samples were analyzed in accordance with the cedures outlined and described for Experiment 1 - Silage Fermentation dy.

Total nitrogen of the dry feces ground through a 20 mesh screen determined by the macro-Kjeldahl procedure.

The micro-Kjeldahl procedure was used to determine total nitrogen urine.

Rumen voltatile fatty acid concentrations were determined on a ackard gas chromatograph. Samples were prepared by mixing five ml of trained rumen fluid with one ml of 25% metaphosphoric acid, centrifuging t 12,000 x g for five minutes. The peak areas were converted to micro-oles per ml and moler percentages by comparison to standard solutions nalyzed at the same time.

Statistical Analysis

All data reported in this dissertation were analyzed on an IBM 500 computer at the Michigan State University Computer Laboratory. alysis of variance and correlation coefficients (AOAC, 1960) have been mputed on all trials in order to more precisely define the significant lationships among the variables studied. Because of unequal numbers in periment 1 - Silage Fermentation Study, a least squares procedure was ed (Harvey, 1960). In the model were included harvests made on ptember 3, 17, October 1, 15, 29 and November 5; pressure levels of 2.5 d 5 psi; and days 1, 2, 3, 5, and 12 of the fermentation. Regular lysis of variance (AOAC, 1960) was used to test the effect of stage of urity and pressure when the process of fermentation was not included. example of the analysis of variance and the Duncan's new multiple range cedures are shown in Appendix I.

IV. RESULTS AND DISCUSSION

Experiment 1 - Silage Fermentation Study

Complete results of this experiment are shown in tabular and graphic form (Figures 7 through 19 and Tables 5 through 11). Results are summarized and presented on (1) the effects of stage of maturity of the corn plant on the resulting silage after twelve days of fermentation in the silo, (2) characterization of the silage fermentation from the time of filling the silo through day 12, (3) interactions of silage maturity and rate of fermentation (items 1 and 2), and (4) the effects of varying silo pressures on silage fermentation parameters.

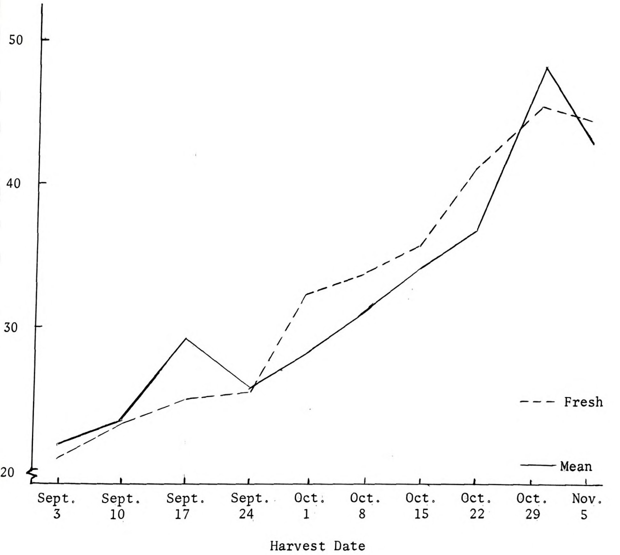
As stated in procedures, a two- to six-hour time lapse occurred between chopping the plant material and collecting the initial fresh sample. Therefore, fermentation was well under way when the fresh sample was collected as verified by chemical analysis. Results of the fresh sample analysis are presented, but not included in the discussion due to the atypical nature of the sample.

Corn Silage Maturity

Dry Matter. Dry matter content of silages at the end of the 12-day ermentation for the fresh material, as well as each of the four pressures udied, are shown in Figure 7. Dry matter values for the fresh material d the mean values for the four pressures studied are graphically shown Figure 7. As would be expected, a highly significant difference

FIGURE 7

Mean Dry Matter Content Relative to Stage of Maturity



21.1	23.4	25.2	25.4	31.3	32.1	35.2	40.6	45.2	43.2
18.1	20.7	27.2	24.3	27.4	32.0	31.5	39.1	48.1	42.9
21.6	23.4	27.3	23.8	28.6	29.1	38.0	37.9	48.2	42.7
21.7	24.9	31.0	26.2	28.7	32.0	34.8	36.3	47.7	39.5
26.9	26.1	32.2	29.1	30.6	29.7	33.5	37.2	49.1	43.0
22.1	23.8	29.4	25.9	28.8	30.7	34.5	37.6	48.3	42.0

significantly different ($P < .01$)

error of the means = 0.990

P < .01) occurred in dry matter content of silages harvested over the eriod September 3 through November 5. Per cent dry matter of the corn lant increased from a low of 22.1% on September 3 in a linear relation-hip to a high of 48.3% on October 29, an increase of 3% per week through he harvest season. No explanations can be offered for the nonlinear esults obtained on September 17 and November 5. Research such as Nevens t al. (1954), Johnson et al. (1967, 1968) and Huber et al. (1968) all eport a similar relationship between dry matter content of silage and arvest date.

Seepage Volume. Volume of seepage (effluent) escaping from the lo during the 12-day fermentation, and expressed as ml per 100 grams of lage placed in the silo, is shown and the mean graphically illustrated Figure 8. Volume was linearly related to both harvest date or dry tter content of the silage and pressure applied to the silo. All dif-rences in seepage volume were highly significant (P < .01).

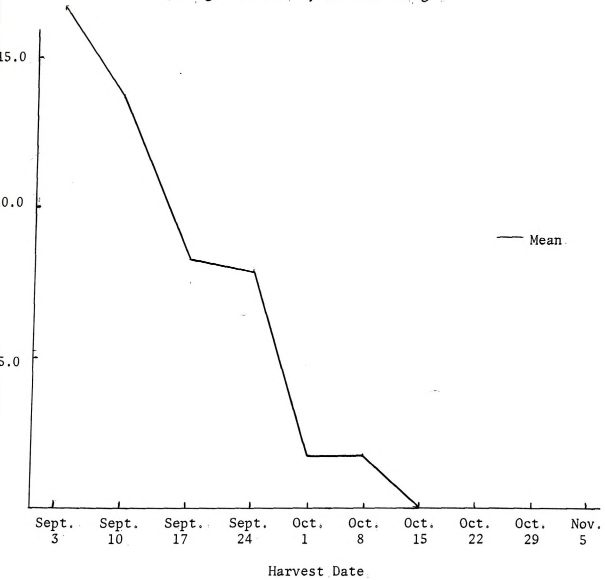
The early harvest (22.1% dry matter) produced the greatest quantity seepage (16.90 ml per 100 gm. of silage) and, as silage dry matter creased, seepage volume decreased, until no seepage was collected when silage reached 34.5% dry matter. Murdock (1954) reported no seepage n corn silage reached 39% dry matter. These data agree with those of ler and Clifton (1965) who concluded that seepage loss was determined marily by the dry matter content of the corn crop.

As volume decreased, dry matter concentration of the seepage reased, as shown in Table 5. This might be explained by relating the page dry matter to maturation of the corn plant. As the plant matures 22.1% dry matter in the September 3 harvest, to 25.9% dry matter in September 24 harvest, the starch content would increase with the

Mean Seepage Volume

FIGURE 8

Mean Seepage Volume (ml/100 gm. fresh sample) Relative to Stage of Maturity of Corn Silage



12.01	5.18	0.76	0	0	0	0	0	0	0
10.37	14.15	5.39	5.75	0	0	0	0	0	0
28.31	21.98	17.83	17.72	3.93	3.95	0	0	0	0
16.90	13.77	7.99	7.82	1.31	1.32	0	0	0	0

significantly different (P < .01)

error the mean = 608.08

TABLE 5

Seepage Parameters

Harvest Date	Sept. 3	Sept. 10	Sept. 17	Sept. 24
% Dry Matter	5.46	6.88	10.26	10.42
% Total Nitrogen[1]	1.41	2.28	2.17	1.70
% Ash[1]	11.41	10.92	7.01	6.91

[1]Per cent of total dry matter.

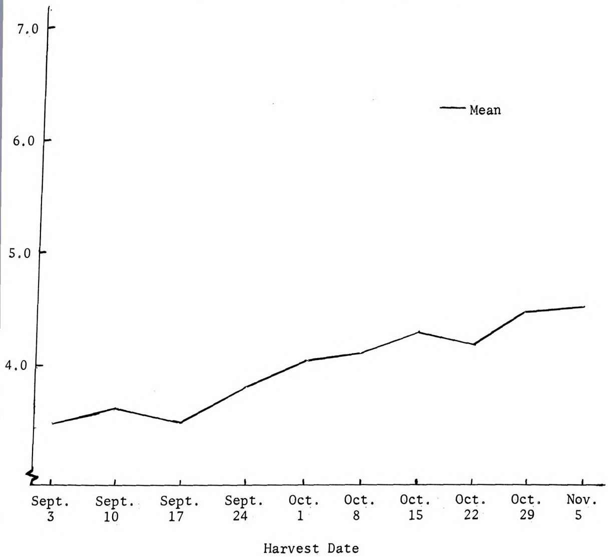
evelopment of the grain portion of the plant. Although analyses were ot conducted, visual appraisal of the seepage samples collected clearly ndicated that a large quantity was expelled within the seepage in the ter harvests. Per cent total nitrogen and ash, expressed on a seepage y matter basis, are also shown in Table 5 with no major differences und.

Fermentation of the seepage was in progress when these samples re collected; therefore, further characterization was not done.

Silage pH. Results of pH determined on the silage after 12 days' rmentation are shown and the mean graphically illustrated in Figure 9. ighly significant increase in pH occurred from 3.52 to 4.65 as the age increased in dry matter from 22.1% to 48.3% which was significantly related with dry matter (r = 0.64--see Table 6). Since these silages e not treated with a buffering and/or neutralizing agent such as lime- ne, urea, etc., pH would be expected to reflect total quantity of anic acids found in the silage. This was the case as verified by a ly significant correlation coefficient of -0.52 and -0.77 (see Table 6) acetic and lactic acid content of the silage, respectively. It has shown at the Michigan Station (Henderson, unpublished data) that e is no relationship between pH and organic acid content when silages treated with buffering and/or neutralizing agents. Often, treated ges with the highest organic acid content will have the highest pH es. When working with untreated silages, pH has been extensively used indicator of silage quality (Barnett, 1954) and these data support concept. However, it is of no value when estimating quality of ed silages.

FIGURE 9

Mean Silage pH Relative to Stage of Maturity



3.40	3.69	3.60	3.81	4.00	4.10	4.45	5.45	5.90	5.63
3.50	3.66	3.50	3.80	4.10	4.02	4.25	3.15	4.30	4.20
3.55	3.55	3.50	3.82	4.05	4.30	4.25	4.20	4.20	4.40
3.61	3.60	3.50	3.80	4.00	4.00	4.10	4.20	4.10	4.35
3.52	3.63	3.53	3.81	4.04	4.08	4.28	4.23	4.63	4.65

re significantly different ($P < .01$)

error of the means = 0.204

Simple Correlations - Fermentation Study

	Seepage Volume, ml	pH	% Dry Matter	% Nitrogen	% Soluble N	% Soluble NPN	% NH_3 - N	% Acetic Acid	% Lactic Acid	Soluble CHO
Seepage volume, ml	1.00									
pH	-0.36*	1.00								
% Dry Matter	-0.32*	0.64**	1.00							
% Nitrogen	0.26	-0.26	-0.55**	1.00						
% H_2O Soluble N	0.47**	-0.62**	-0.61**	0.50**	1.00					
% H_2O Soluble NPN	0.59**	-0.68**	-0.65**	0.50**	0.76**	1.00				
% NH_3 - N	0.34*	-0.66**	-0.78**	0.60**	0.66**	0.66**	1.00			
% Acetic Acid	0.33*	-0.52**	-0.82**	0.30	0.56**	0.70**	0.64**	1.00		
% Lactic Acid	0.38*	-0.77**	-0.81**	0.51**	0.74**	0.76**	0.80**	0.70**	1.00	
Soluble CHO	0.44**	-0.48**	-0.56**	0.44**	0.68**	0.67**	0.44**	0.47**	0.53**	1.00

	Critical Value[1]
*P < .05	0.31
**P < .01	0.40

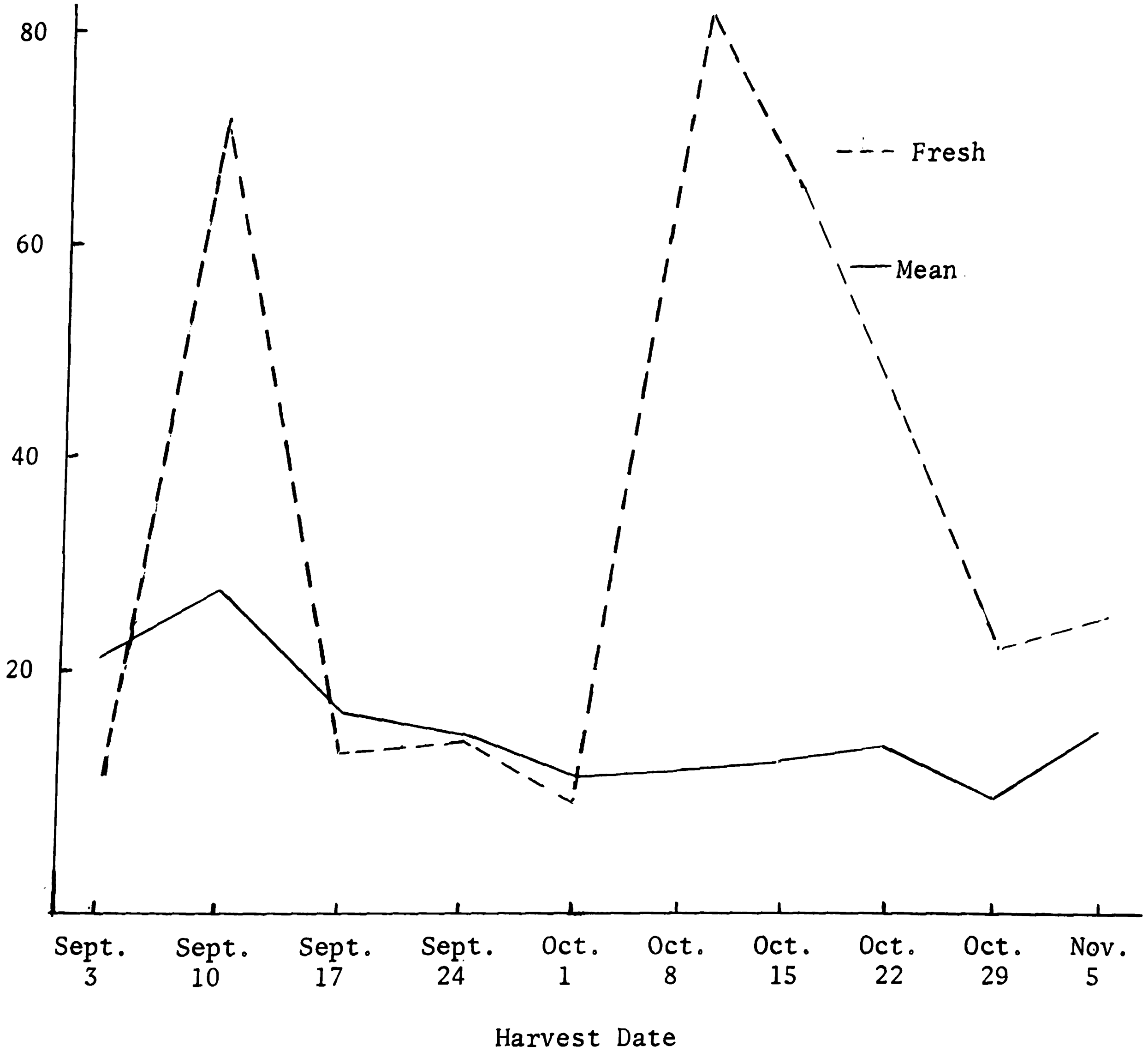
[1]Snedecar (1946)

Soluble Carbohydrate. Results of water soluble carbohydrate levels in corn silage conducted on the fresh silage sample and after 12 days in the silo are shown in Figure 10, with mean values graphically illustrated. The erratic values obtained on the fresh sample are probably due to the partial fermentation which had occurred prior to taking the sample as explained at the beginning of this section. A small but consistent and highly significant decrease with maturity occurred in soluble carbohydrate content of the silage sample taken after 12 days in the silo. This resulted in a highly significant correlation coefficient of -0.56 (see Table 6) between per cent dry matter and soluble carbohydrate level. A highly significant ($P < .01$) correlation was also found between soluble carbohydrate content and acetic and lactic acid levels ($r = 0.47$ and 0.53, respectively). Thus, it appears from these data, that soluble carbohydrate served as a primary substrate for both acetic and lactic acid producing bacteria. This is verified by the work of Johnson et al. (1966), who reported decreasing levels of soluble carbohydrate with advancing stages of corn plant maturity. They also found a close relationship between soluble carbohydrate content of fresh corn plant material and acetic and lactic acid levels found in the resulting corn silage.

Acetic Acid. Acetic acid levels found in the silage after 12 days of fermentation are shown and graphically illustrated in Figure 11. As stated in the procedures section, analyses were conducted for all volatile fatty acids reported to be found in silage (acetic, propionic, butyric, isobutyric, valeric and isovaleric acids). However, quantities of these acids were too low to be of any consequence, so values are not presented with the exception of acetic. These findings are in agreement with the

FIGURE 10

Mean Soluble Carbohydrate Levels Relative to Stage of Maturity



10.43	72.65	13.49	14.96	9.58	81.00	65.20	44.83	22.85	26.39
20.99	33.82	18.39	13.17	13.14	4.32	11.43	7.67	7.07	15.38
20.37	35.90	15.38	17.65	9.79	17.18	11.58	11.08	9.96	16.39
21.20	20.88	21.94	17.56	11.85	13.13	10.92	17.08	9.64	16.20
29.74	22.20	14.91	14.43	12.42	12.12	13.73	14.52	12.22	14.88
23.08	28.20	17.65	15.70	11.80	11.69	11.92	12.59	9.72	15.71

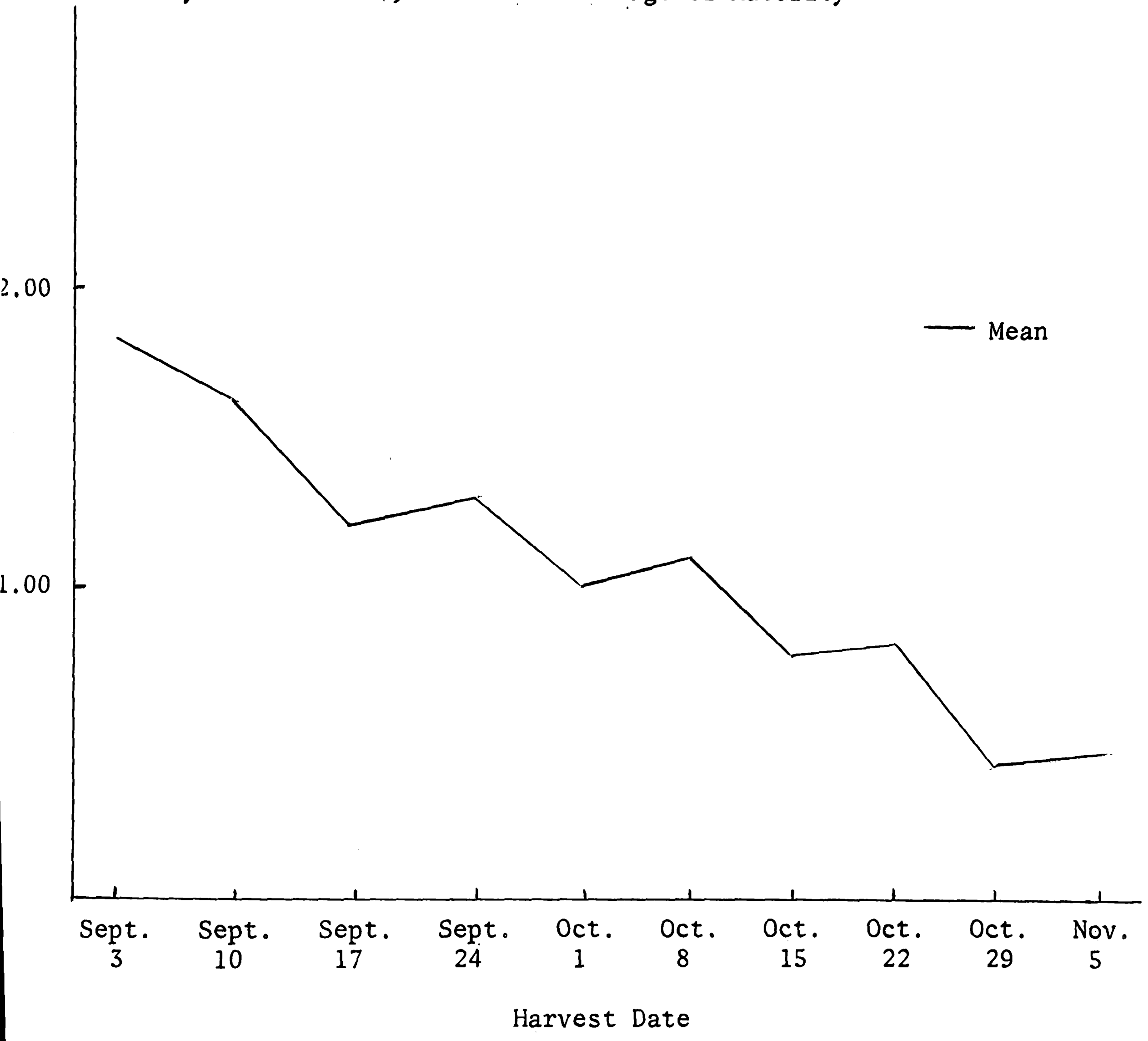
re significantly different ($P < .01$)

l error of the means = 1.988

Acetic Acid (Per Cent of Dry Matter)

FIGURE 11

Mean Acetic Acid Levels (Per Cent on Dry Matter Basis) Relative to Stage of Maturity



	2.24	1.88	0.97	1.21	0.81	1.19	0.86	1.77	0.14	0.11
i	2.29	1.47	1.43	1.32	1.11	1.11	0.80	0.44	0.53	0.56
	1.92	1.80	1.22	1.30	1.23	1.15	0.69	0.57	0.49	0.65
	1.09	1.40	1.30	1.39	1.08	1.04	0.84	0.55	0.44	0.43
	1.89	1.64	1.23	1.31	1.06	1.12	0.80	0.83	0.40	0.44

re significantly different ($P < .01$)

d error of the means = 0.156

results obtained by Barnett (1954) who found acetic acid to be the primary VFA in corn silage. Mean acetic acid levels (Figure 11) progressively decreased from a high of 1.89% of silage DM for the September 3 harvest to a low of 0.44% for the November 5 harvest. This decrease was highly significant ($P < .01$) and was significantly correlated ($P < .01$) with silage dry matter ($r = -0.82$), soluble carbohydrate ($r = 0.47$), nonprotein nitrogen ($r = 0.70$), and many other fermentation parameters as shown in Table 6.

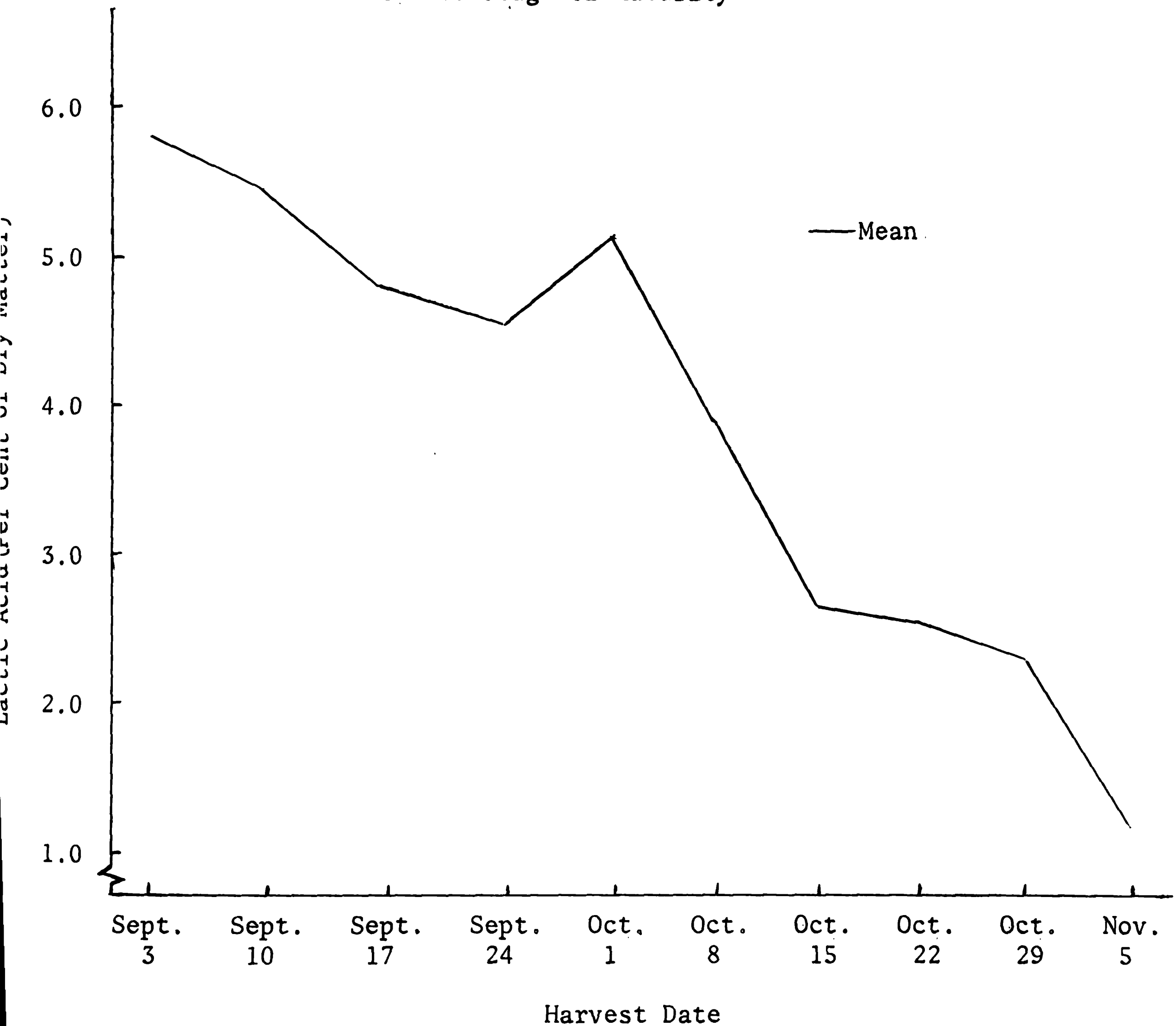
A similar relationship between corn silage maturity and acetic acid levels was reported by Johnson _et al_. (1967, 1968) and Gordon _et al_. (1968).

Lactic Acid. Mean values for lactic acid and the relationship to silage maturity are shown and graphically illustrated in Figure 12. As was the case with acetic acid, levels of lactic acid found in the silage sampled after 12 days of fermentation, decreased at a highly significant ($P < .01$) rate from a high of 5.82% of silage dry matter for the September 3 harvest to a low of 1.27% for the November 5 harvest. Likewise, highly significant ($P < .01$) correlation coefficients were found between lactic acid levels and silage dry matter ($r = -0.81$), soluble carbohydrate ($r = 0.53$) and nonprotein nitrogen content ($r = 0.76$). Lactic acid levels were found to be approximately 3.7 times greater than acetic acid at all stages of maturity.

Quantitative levels of both acetic and lactic acid relative to corn silage maturity and the relationship of these levels to other fermentation parameters are in complete agreement with the findings of Johnson _et al_. (1967, 1968), Barnett (1954), Watson and Nash (1960) and Gordon _et al_. (1968).

FIGURE 12

Mean Lactic Acid Levels (Per Cent on Dry Matter Basis)
Relative to Stage of Maturity



i	6.52	5.80	4.04	3.79	3.50	3.51	1.78	0.41	0.93	0.00
psi	6.11	5.90	6.01	5.50	6.08	4.48	3.00	2.96	2.82	1.80
i	5.35	4.66	4.45	5.01	4.60	3.78	2.99	3.86	2.60	1.52
si	5.28	5.75	4.81	4.48	6.14	4.08	2.81	3.04	2.44	1.72
	5.82	5.53	4.82	4.70	5.08	3.98	2.65	2.57	2.20	1.27

s are significantly different ($P < .01$)

lard error of the means = 0.338

Total Nitrogen. Total nitrogen content of silages for the various harvest dates is shown in Figure 13, with mean and fresh sample values graphically illustrated. Total nitrogen of the fresh material and mean values for the silage after 12 days of fermentation showed increases and decreases from one harvest date to another. Even though these variations existed and differences relative to harvest dates were small, the mean value for per cent nitrogen significantly ($P < .01$) decreased as stage of maturity advanced. This is further substantiated by a highly significant ($P < .01$) correlation, of -0.55 between total nitrogen and dry matter content of the silage.

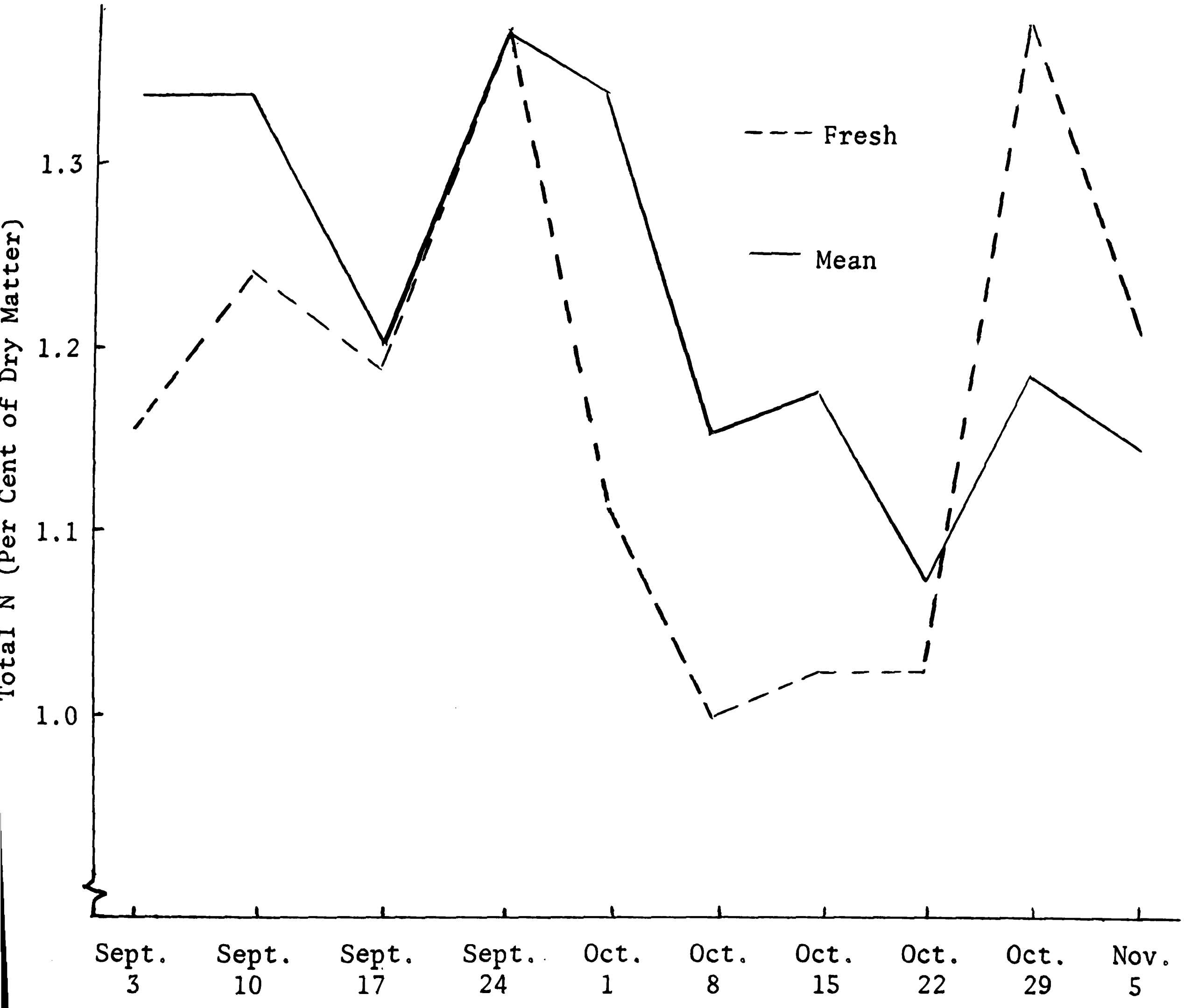
These data do not show a clear cut linear relationship of decreasing nitrogen content with advancing stages of maturity. The lack of linearity could be due to silage sampling error or growth patterns of the plant prior to harvest as affected by growing conditions.

Relatively small but significant decreases in total nitrogen content of corn silage relative to advancing stages of maturity have been reported by Hopper, 1925; Byers and Ormiston, 1966; Buck, Merrill, Coppock and Slack, 1969; Johnson et al., 1966 and Sprague and Leparulo, 1965.

Water Soluble Nitrogen. Water soluble nitrogen expressed as a per cent of dry matter for all harvest dates and pressures studied is shown in Figure 14. Values for the fresh sample and mean values for the samples taken after 12 days of fermentation are also graphically illustrated. Water soluble nitrogen decreased significantly ($P < .01$) with maturity from a high of 0.43% of dry matter for the September 3 harvest to 0.23% of dry matter for the November 5 harvest. A highly significant ($P < .01$) correlation (see Table 6) of -0.61 existed between water soluble nitrogen and dry matter content of the silage.

FIGURE 13

Mean Total Nitrogen (Per Cent of Dry Matter)
Relative to Stage of Maturity



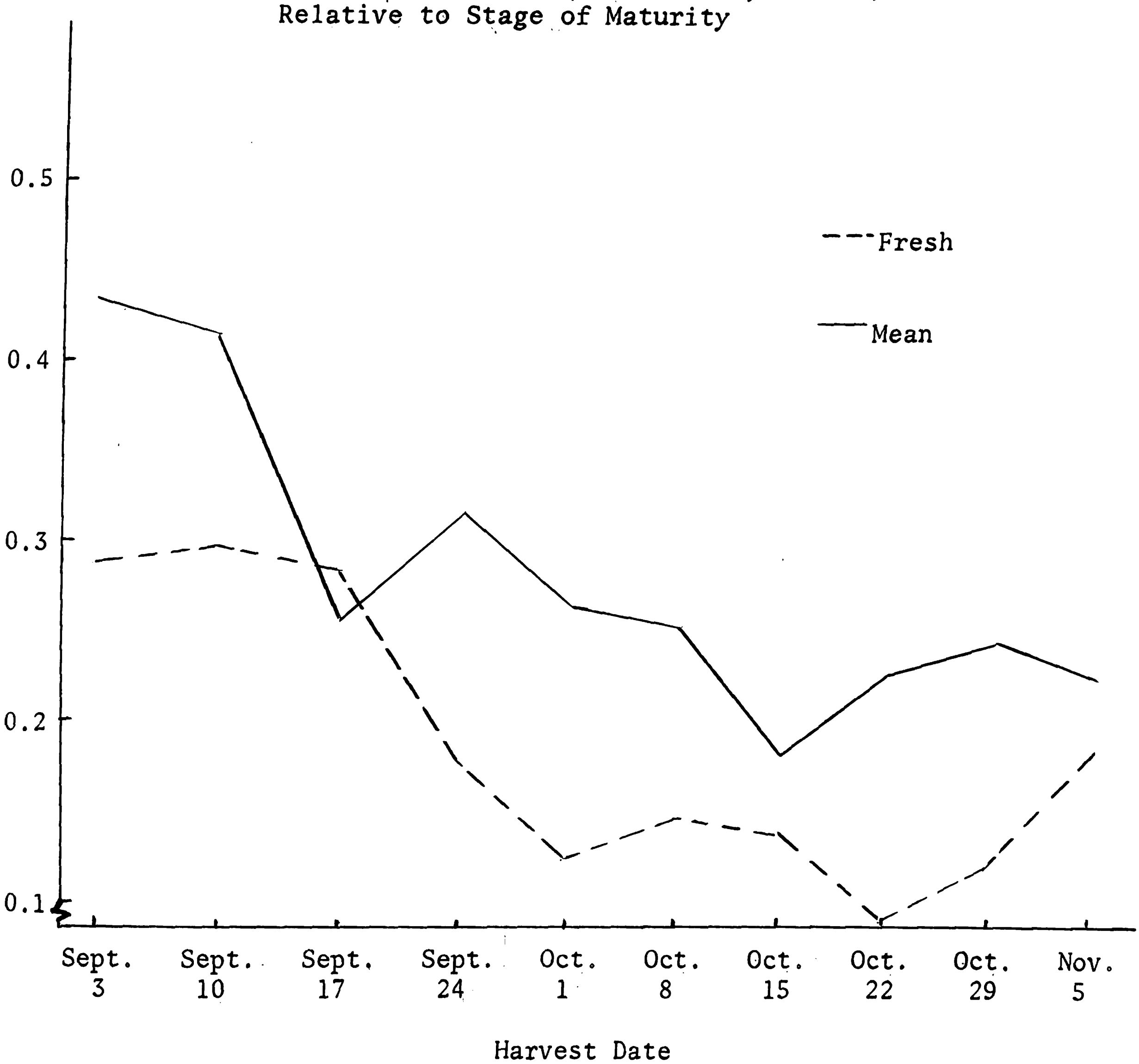
	1.16	1.24	1.19	1.41	1.11	0.98	1.02	1.02	1.40	1.21
	1.31	1.44	1.15	1.40	1.36	1.01	1.34	0.86	1.29	1.26
...si	1.36	1.33	1.17	1.40	1.40	1.21	0.95	1.07	1.19	0.88
	1.35	1.23	1.26	1.40	1.30	1.24	1.25	1.10	1.08	1.30
	1.35	1.36	1.20	1.30	1.30	1.17	1.19	1.27	1.19	1.16
	1.34	1.34	1.20	1.38	1.34	1.16	1.18	1.08	1.19	1.15

...are significantly different (P < .01)

...rd error of the means = 0.057

FIGURE 14

Water Soluble Nitrogen (Per Cent of Dry Matter)
Relative to Stage of Maturity



	0.292	0.299	0.289	0.176	0.129	0.147	0.142	0.084	0.121	0.188
	0.402	0.406	0.329	0.249	0.217	0.217	0.203	0.097	0.150	0.176
si	0.493	0.443	0.379	0.284	0.252	0.252	0.161	0.242	0.256	0.243
	0.400	0.360	0.110	0.249	0.261	0.261	0.174	0.284	0.276	0.257
	0.437	0.451	0.250	0.302	0.264	0.264	0.216	0.301	0.291	0.249
	0.433	0.415	0.267	0.310	0.271	0.249	0.189	0.231	0.243	0.231

are significantly different ($P < .01$)

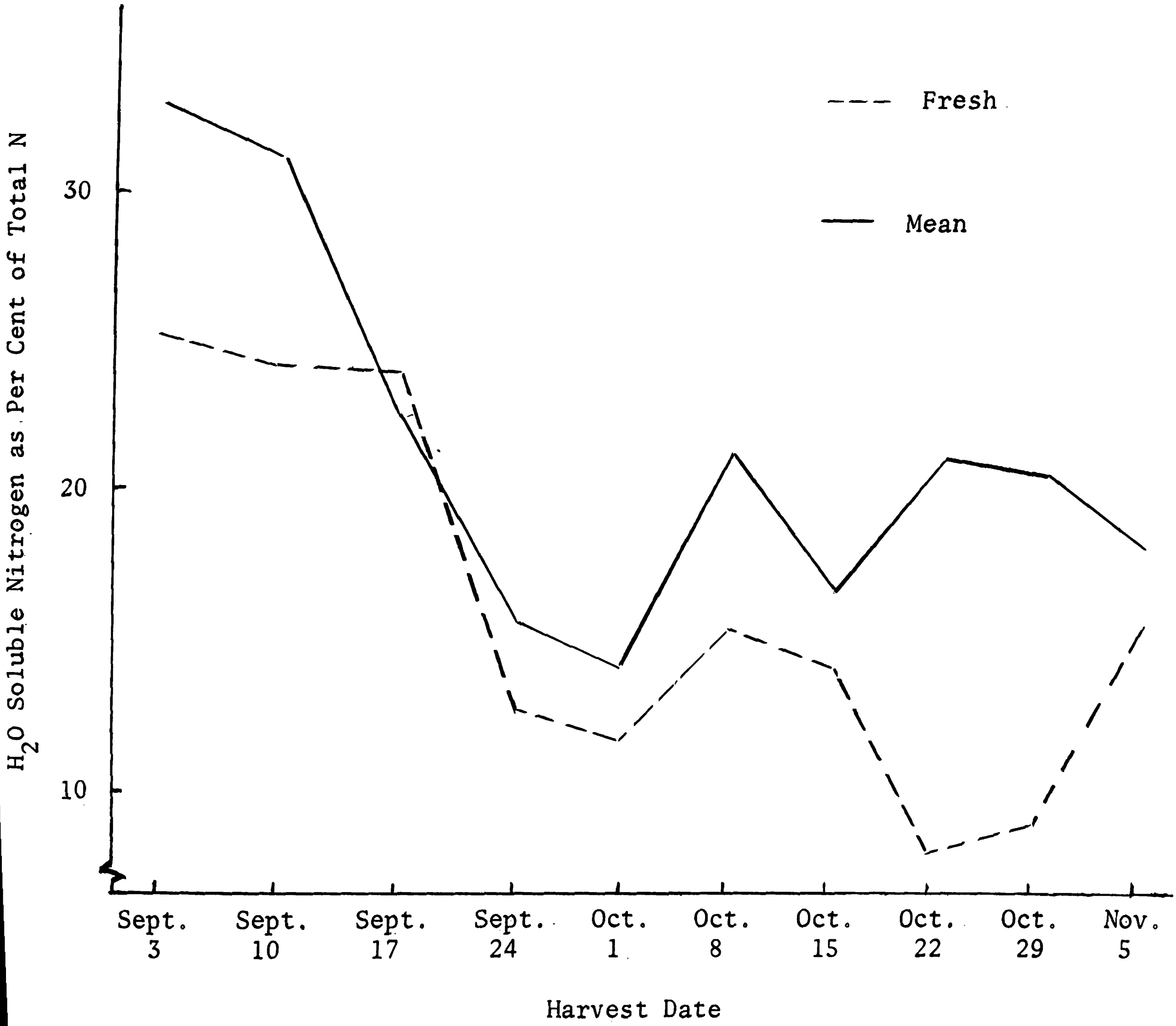
rd error of the means = 0.027

Although total nitrogen followed the same pattern, as previously discussed, the magnitude of decrease across harvest dates for water soluble nitrogen was at an accelerated rate, as shown in Figure 15 where water soluble nitrogen represented 32.25% of total nitrogen for the September 3 harvest and only 18.4% for the November 5 harvest. This represents a 46.7% reduction, whereas total nitrogen was decreased only 14% between the September 3 and November 5 harvests. Brody (1965) reported protein hydrolysis ranging from 29% for moist silage to 18% for dryer silages. Although protein hydrolysis was not directly measured, it appears that protein hydrolysis was actively taking place, as evidenced by a consistently lower level of water soluble nitrogen found in the fresh material than the ensiled material as shown in Figure 14. Differences were similar across all harvest dates. Thus, these data would indicate that the extent of protein hydrolysis was not influenced by harvest date or dry matter content of the silage.

Water Soluble Nonprotein Nitrogen. Levels of water soluble nonprotein nitrogen expressed as a per cent of silage dry matter are shown in Figure 16 with values for the fresh samples and the 12-day fermentation samples graphically illustrated. After examining Figures 14 and 16, it can be readily seen that water soluble nonprotein nitrogen and water soluble protein nitrogen follow almost identical patterns and, no doubt, represent the same source of nitrogen in both cases. Therefore, the previous discussion for water soluble nitrogen applies also for water soluble nonprotein nitrogen. It was found at this station (Henderson, unpublished data) in controlled experiments with silage that water soluble nonprotein nitrogen accounted for approximately 95% of the water soluble nitrogen. Although these data show higher values for water soluble NPN than water soluble

FIGURE 15

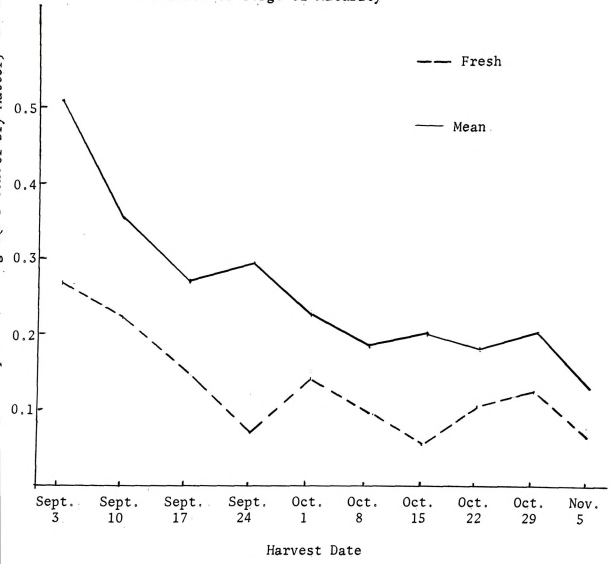
Water Soluble Nitrogen Expressed as a Per Cent of Total Nitrogen Relative to Stage of Maturity



sh, %	25.2	24.1	24.3	12.48	11.6	15.0	13.92	8.23	8.64	15.54
si, %	30.7	28.2	28.6	12.57	11.32	21.5	15.1	11.3	11.6	14.0
psi, %	36.3	33.3	32.4	16.57	14.1	20.8	16.9	22.6	21.5	27.61
i, %	29.6	29.3	8.7	16.5	13.62	21.0	13.9	25.8	25.6	19.8
si, %	32.4	33.2	20.83	15.08	16.85	22.6	18.15	23.7	24.5	21.5
n %	32.25	31.00	22.25	15.14	14.03	21.48	16.02	21.39	20.8	18.4

FIGURE 16

Soluble Nonprotein Nitrogen (Per Cent Dry Matter)
Relative to Stage of Maturity



0.270	0.221	0.155	0.087	0.142	0.105	0.064	0.111	0.124	0.083
0.486	0.384	0.212	0.262	0.155	0.158	0.181	0.100	0.128	0.052
0.575	0.381	0.205	0.301	0.261	0.220	0.186	0.236	0.244	0.170
0.453	0.280	0.331	0.311	0.258	0.221	0.183	0.225	0.200	0.148
0.500	0.367	0.341	0.305	0.244	0.170	0.251	0.211	0.246	0.190
0.504	0.353	0.272	0.396	0.228	0.192	0.200	0.193	0.205	0.140

e significantly different ($P < .01$)

rors of the means = 0.022

nitrogen for four of the ten harvests, on comparing the overall means, water soluble NPN accounts for 94.37% of the soluble nitrogen, and the exceptions referred to for individual harvests are probably due to sampling errors. Both values were determined from the same silage extract, but utilizing two different samples.

Ammonia Nitrogen. Ammonia nitrogen levels expressed as a per cent of silage dry matter are shown in Figure 17. The fresh samples and the mean of the 12-day fermentation samples are graphically illustrated. As was the case with all other nitrogen parameters studied, ammonia levels significantly decreased across harvest dates and were significantly correlated ($r = 0.78$, $P < .01$) with silage dry matter. Values were extremely low and ranged from a high of 0.07% of dry matter for the September 3 harvest to a low of 0.02% for the November 5 harvest, and made up an average of 3.47% of the total nitrogen for all harvest dates. Johnson et al. (1967) reported similar low levels and the same relationship to maturity. Therefore, ammonia nitrogen in untreated silages appears to be of minor importance in silage fermentation.

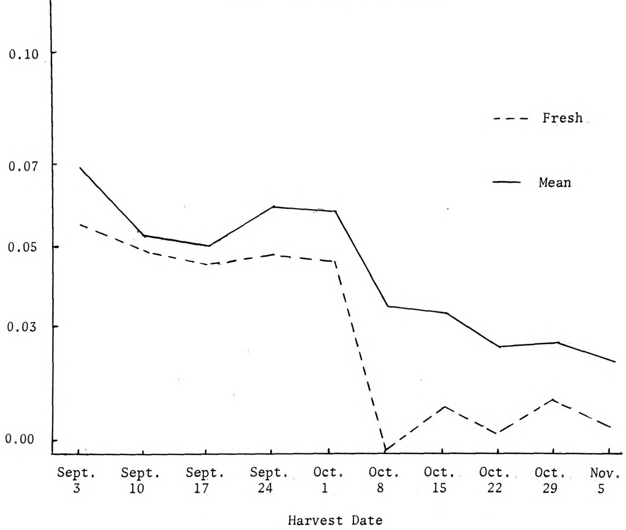
Correlation Coefficients of Fermentation Parameters. Simple linear correlation coefficients of all previously discussed parameters have been conducted and are presented in Table 6. The pertinent values on this table have been previously discussed and referred to in the appropriate sections.

Fermentation by Days

Analysis of silage samples taken fresh and on days 1, 2, 3, and 5 during the fermentation period, as well as the ensiled material at the end of the 12-day fermentation study, are presented in Table 7 and graphically illustrated in Figures 18 and 19.

FIGURE 17

Ammonia Nitrogen (Nitrogen per 100 gm Dry Matter)
Relative to Stage of Maturity



esh	0.056	0.049	0.047	0.049	0.048	0.000	0.013	0.007	0.014	0.010
ɔsi	0.074	0.058	0.051	0.049	0.064	0.023	0.028	0.010	0.011	0.013
5 psi	0.069	0.062	0.064	0.069	0.061	0.036	0.025	0.032	0.033	0.020
ɔsi	0.064	0.064	0.026	0.066	0.061	0.036	0.039	0.033	0.028	0.026
psi	0.067	0.025	0.060	0.063	0.057	0.040	0.031	0.024	0.030	0.029
n	0.069	0.052	0.050	0.062	0.061	0.034	0.031	0.025	0.026	0.022

ns are significantly different ($P < .01$)

ɪdard error of the means = 0.005

TABLE 7

Mean Silage Parameters Relative to the Progress of Fermentation

Mean[2]	Days of Fermentation						s.e.[1]
	Fresh	1	2	3	5	12	
pH	5.51	4.59	4.59	4.48	4.66	3.98 **	0.034
% Dry Matter, %	33.53	33.20	33.13	33.66	32.61	34.15 **	0.787
% Nitrogen, %	1.18	1.17	1.30	1.18	1.25	1.24 **	0.042
% H_2O Soluble Nitrogen,%	0.193	0.187	0.191	0.153	0.191	0.273**	0.0167
% H_2O Soluble NPN, %	0.140	0.187	0.178	0.195	0.182	0.268**	0.0137
% NH_3 - N, %	0.031	0.023	0.014	0.026	0.024	0.043**	0.004
% Acetic Acid, %	0.00	1.043	1.127	1.399	1.529	1.077**	0.085
% Lactic Acid, %	0.00	0.981	1.333	1.713	2.066	3.943**	0.146
Soluble CHO, mg/gm	24.49	47.10	42.99	22.16	20.65	14.60 **	2.755

** P .01

[1]s.e. are approximate, using an average of eight observations per mean.

[2]All values expressed on a dry matter basis

FIGURE 18

Mean pH and Carbohydrate Fractionization Relative to the Process of Fermentation

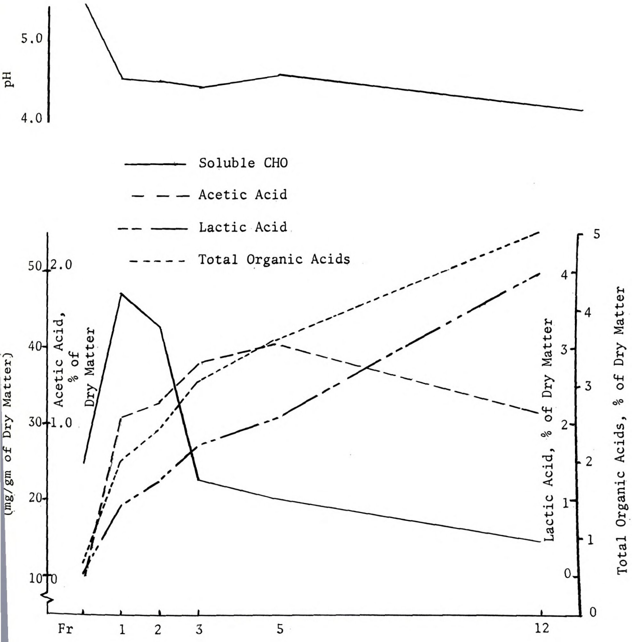
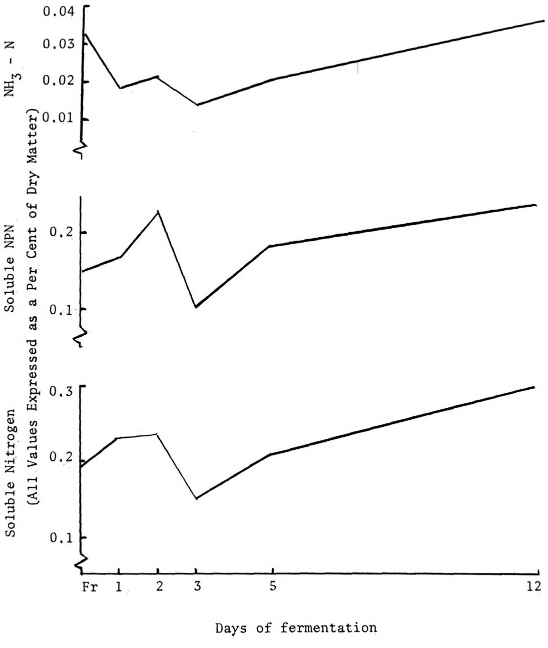


FIGURE 19

Mean Nitrogen Fractionization
Relative to the Process of Fermentation



As shown in Figure 18, pH decreased very rapidly from 5.55 in the fresh material to 4.59 on the first day of fermentation and further reduced to 3.98 during the remaining 11 days. Total acetic and lactic acid levels were 2.02% of silage dry matter on day 1 and were 5.02 on day 12. Thus, reduction in pH is accompanied by an expected level of organic acid accumulation. The rate of production of lactic acid appeared to be linear from day 1 through day 12, whereas the rate of production of acetic acid appeared to increase rather rapidly through day 3, level off from day 3 to day 5 and then decrease through day 12. Values for acetic acid are in agreement with Barnett (1954) who concluded that acetic acid increased very rapidly through the first two phases of fermentation (day 1 through day 3). He further concluded that acetic acid production continued at a slower rate thereafter, which is in conflict with these data which show a net reduction in total acetic acid levels following day 5. Barnett (1954) also concluded that lactic acid increases at a slow rate during phase one and two but at an accelerated rate later in the fermentation (phases 3 and 4). These data do not support this conclusion, as previously pointed out.

The net reduction in acetic acid production following day 5 may be explained on the basis that acetic acid was used as a bacterial substrate (energy source) by lactic acid producing bacteria which continues to increase in activity throughout the 12-day fermentation period.

Soluble carbohydrate levels, as shown in Table 7 and Figure 18 increase very rapidly on day 1, appeared to level off on day 2, decrease very rapidly on day 3 and decrease at a very slow rate through day 12. It seems clear from these data that soluble carbohydrate levels and total organic acid levels are negatively associated. Organic acid

levels increased at a rate approximately two times greater than the reduction in soluble carbohydrate. Johnson et al. (1966a) showed a similar relationship between soluble carbohydrate and lactic acid content of corn silage. This relationship would be expected if an anaerobic atmosphere existed in which anaerobic glycolysis could occur by action of the active bacteria. Each mole of simple sugar; e.g. glucose, metabolized in this manner would produce two moles of lactic acid.

Soluble nitrogen fractions shown in Table 7 and Figure 19 increased linearly from day 1 through day 12. Increasing values for nitrogen fractions during the fermentation would indicate that proteolysis continued to occur throughout the 12-day fermentation period. Data on total nitrogen level results are variable and inconsistent, and differences obtained during the 12-day fermentation are probably due to sampling error. Little or no change in total nitrogen occurred, as would be expected.

Interactions Between State of Maturity and Rate of Fermentation. There were four significant interactions between stage of maturity and fermentation rate; (1) pH, (2) per cent acetic acid, (3) per cent lactic acid,and (4) soluble carbohydrate.

The mean pH values and deviations from the mean for each harvest and the day of fermentation are shown in Table 8. Upon examination of these data, it is clear that in earlier harvests, the pH decreased linearly throughout the 12-day fermentation period, whereas, in later harvests, the pH increased through day 5, and then decreased to day 12.

As a possible explanation of this interaction, bacterial activity in the high moisture silage, pointed out previously, would become very active early in the fermentation. This accelerated bacterial growth is stimulated by the availability of high levels of soluble carbohydrate and

TABLE 8

Mean pH and Deviations From the Mean Involved in the Interaction of Stage of Maturity and Process of Fermentation

		Days 1	2	3	5	12	$\bar{x}$
	2	(0.00) 4.01	(0.00) 4.01	(0.01) 3.91	(-0.13) 3.95	(0.12) 3.50	(-0.58) 3.88
	4	(0.34) 4.59		(0.04) 4.18	(-0.24) 4.08	(-0.14) 3.50	(-0.34) 4.12
	6	(0.04) 4.46	(-0.05) 4.37	(-0.02) 4.29	(-0.22) 4.27	(0.25) 4.06	(-0.17) 4.29
Harvest	8	(-0.02) 4.73	(-0.03) 4.72	(0.02) 4.66	(-0.08) 4.74	(0.11) 4.25	(0.16) 4.62
	10		(0.08) 5.06		(0.04) 5.09	(-0.12) 4.25	(0.39) 4.85
	11	(-0.36) 4.77		(-0.05) 4.97	(0.63) 5.83	(-0.22) 4.30	(0.54) 5.00
	$\bar{x}$	(0.13) 4.59	(0.13) 4.59	(0.02) 4.48	(0.20) 4.66	(-0.48) 3.98	4.46

the anaerobic condition in the mass. In the later harvests (dryer silage) soluble carbohydrate would be lower and a less anaerobic condition would exist and, therefore, bacterial growth would be less. Concurrently, proteolytic enzyme activity of the plant would continue as normal and form volatile bases which could account for the rise in pH. At some unknown point after five days of fermentation, the bacterial population becomes active and their production of organic acids overshadows the plant proteolysis, which lowers the pH of the mass to the level found on day 12.

The mean per cent lactic acid and deviations from the means by harvest dates and days of fermentation are shown in Table 9. These data support the proposed explanation for the interaction involving pH, in that the per cent lactic acid increases linearly in the early harvested, high moisture silages. However, in the later harvests, lower in moisture content, lactic acid production did not start until after day 5. The production of lactic acid is thought to be a direct indication of bacterial activity.

Silo Pressure

The effect of silo pressure on various silage fermentation parameters is shown in Table 10.

It should be pointed out again that the silage stored in the zero pressure silo was not maintained in an anaerobic atmosphere.

Silo pressure had a profound effect on volume of seepage which was nil at zero pressure and increased in a linear fashion to 15.62 ml per 100 grams of silage stored at 10 psi. For all other fermentation parameters studied and presented in Table 10, there appeared to be little or

TABLE 9

Mean Lactic Acid Value and Deviations from the Mean Involved in the Interaction of Stage of Maturity and Process of Fermentation

		Days 1	2	3	5	12	$\bar{x}$
Harvest	2	(-0.88) 2.39	(-0.17) 3.45	(0.94) 4.94	(0.61) 4.97	(-0.50) 5.73	(2.29) 4.30
	4	(0.11) 1.82		(-0.51) 1.93	(-0.15) 2.65	(0.55) 5.22	(0.73) 2.75
	6	(-0.36) 1.53	(-0.15) 2.09	(-0.22) 2.40	(0.24) 3.22	(0.49) 5.34	(0.91) 2.92
	8	(0.26) 0.22	(0.12) 0.43	(-0.23) 0.46	(-0.22) 0.83	(0.07) 2.99	(-1.02) 0.99
	10		(0.20) 0.34		(-0.15) 0.73	(-0.05) 2.70	(-1.19) 0.82
	11	(0.87) 0.12		(0.02) 0.00	(-0.33) 0.01	(-0.56) 1.65	(-1.73) 0.27
	$\bar{x}$	(-1.03) 0.98	(-0.67) 1.33	(-0.29) 1.71	(0.06) 2.07	(1.93) 3.94	2.01

TABLE 10

Mean Silage Parameters Relative to Silo Pressures

	Pressure per square inch				s.e.[1]
	0	2.5	5.0	10.0	
Seepage Volume, ml.	0.000	339.000	706.500	2168.000	384.58
pH	4.403[a]	3.848	3.982	3.926	0.1288
Per Cent Dry Matter	31.130[a]	32.060	32.280	33.740[b]	0.6264
Per Cent Nitrogen	1.242	1.196	1.251	1.249	0.0363
Per Cent Soluble Nitrogen	0.2489	0.3102	0.2722	0.3041	0.0173
Per Cent Soluble Non-protein Nitrogen	0.2118[Aa]	0.2779[B]	0.2602[a]	0.2825[B]	0.0130
Per Cent NH_3 Nitrogen	0.0404	0.0471	0.0443	0.0426	0.0032
Per Cent Acetic Acid	1.1180	1.106	1.102	0.956	0.0984
Per Cent Lactic Acid	3.028[A]	4.466	3.882	4.055	0.2140
Soluble Carbohydrates	14.537	16.528	16.040	16.117	1.2574

[1]Ten observations per mean.
[A]$P < .05$.
[a]$P < .01$.

Values with no subscript or having the same subscript are not significantly different.

no difference between silages stored under 2.5, 5, and 10 psi. The 5 psi silo would probably be the most representative of the normal upright farm silos, as reported by Yu, Boyd and Menear (1963). However, virtually all values differed for silages stored under zero psi. Therefore, all degrees of pressure applied in this study resulted in an anaerobic atmosphere which produced a high quality silage and no benefit was derived from pressures above 2.5 psi.

On the other hand, zero pressure was not sufficient to maintain an anaerobic atmosphere. As a consequence, silage produced at 0 pressure was inferior in all fermentation parameters studied.

Other authors have reported pressure measurements in the silo, but none of those reviewed reported the effects of pressure on silage fermentation.

Temperature of the silage mass as shown in Table 11 followed the same pattern as previously discussed. All degrees of pressure applied resulted in virtually no increase in temperature above ambient, whereas a rise of 2.83^{o} C above ambient was observed on day 1 in the silage stored at zero psi. This relative increase in temperature continued throughout the 12-day fermentation.

The temperatures reported in this study are extremely low, ranging around 25^{o} C. They may not be representative of normal silo conditions because of the small volume of silage and the rapid dissipation of any temperature which might have been produced during the fermentation. Babcock and Russell (1900) concluded that good silage could be made at these temperatures, however.

TABLE 11

Mean Temperatures Expressed as Deviations from Ambient Temperatures Relative to Silo Pressure

	Pressure per square inch				s.e.[1]
	0	2.5	5.0	10.0	
	Temperature (Deviation from ambient temperature, degrees C.)				
Day 1	$2.83^{\circ A}$	0.71°	0.13°	-0.19°	0.354
Day 2	$1.05^{\circ A}$	-0.10°	-0.32°	-0.89°	0.279
Day 3	$1.01^{\circ a}$	0.09°	0.06°	-0.30°	0.322
Day 4	$1.03^{\circ a}$	0.45°	0.29°	0.03°	0.229
Day 5	$0.90^{\circ A}$	-0.27°	-0.35°	-0.65°	0.170
Day 6	$0.85^{\circ A}$	-0.30°	-0.55°	-0.78°	0.185
Day 7	$0.68^{\circ A}$	-0.61°	-0.80°	-0.90°	0.304
Day 8	$1.00^{\circ A}$	-0.54°	-0.57°	-0.68°	0.314
Day 9	$0.05^{\circ A}$	-1.22°	-1.30°	-1.33°	0.206
Day 10	$0.78^{\circ A}$	-0.14°	-0.24°	-0.35°	0.138
Day 11	$0.72^{\circ A}$	-0.45°	-0.52°	-0.88°	0.210

[1] Ten observations per mean
[a] $P < .05$
[A] $P < .01$

Values with no subscript or having the same subscript are not significantly different.

Experiment 2 - Feeding Trial 1

Weather data, including freeze dates, snowfall and wind velocity, was recorded during the silage harvesting periods and is reported in Table 12. There was no frost prior to the September 13 harvest date. Between September 16 and October 20, the conclusion of the October harvest, freezing occurred on five different nights. There was no snowfall, and the wind reached 20.3 mph on one day. Between October 20 and November 15, freezing occurred on 14 of the 26 nights. It also snowed a total of four days with a maximum accumulation of nine inches. All snow had melted prior to the November harvest. Maximum wind velocity of 19.7 mph, occurred on one day during this time.

Table 13 shows the results of analysis of the silage samples taken during harvest and again during the course of the experiment. These data characterize changes which occur during the fermentation process and are in complete agreement with the results obtained in Experiment 1 - Fermentation Study, involving a wide range of silages harvested at various dry matters which has been previously presented and discussed.

Chemical Analysis of Silage. Results of the chemical analyses conducted on the six composite silage samples taken during the course of the feeding trial are shown in Tables 14 and 15.

Dry matter content of the corn silage averaged 28.2% for the September, 48.2% for the October, and 59.6% for the November harvested silages. In each case, the fine chopped silage had a higher dry matter value than medium chopped silage (September, 30.4% vs. 27.9%; October, 49.6% vs. 45.4%; November 60.7% vs. 58.2%). This was probably due to the greater moisture evaporation from the more finely chopped corn plant during the harvesting process.

TABLE 12

Weather Data During the 1966 Harvest[1]

	Days Temp. Dropped Below Freezing		Snowfall		Wind
	Date[2]	Temp.	Amount	Accumulation	Mph high during period
Prior to Sept. 16					
September 16 - First Harvest	Sept. 16	31°			
	26	27°			
	Oct. 1	30°			
	4				20.3
	6	25°			
	12	26°			
October 20 - Second Harvest	Oct. 20	28°			
	25	26°			
	26	23°			
	29	29°			
	30	15°		0	
	Nov. 2	25°	2.5"		
	3	24°	5.5"	8"	19.7
	4	9°	Trace	9"	
	5	24°	0.1"	7"	
	6	29°		5"	
	7			2"	
	12	21°		0	
	13	19°			
	14	24°			
November 15 - Third Harvest	Nov. 15	21°			

[1]Weather data reported as recorded at the U. S. Weather Bureau, Capitol City Airport, Lansing, Michigan.

[2]Dates not listed are days during which the temperature did not fall below freezing.

TABLE 13

TABLE 13

Mean Silage Parameters Relating Fresh and Ensiled Materials Used in Experiment 2 - Feeding Trial 1

	September			October			November		
	Fresh	Ensiled	Change	Fresh	Ensiled	Change	Fresh	Ensiled	Change
% Dry Matter		28.21			48.15			59.55	
pH	5.90	3.74		5.30	4.39		5.30	5.35	
			All values expressed on a dry matter basis						
% Lactic Acid	0	5.85		0	1.51		0	0.389	
% Acetic Acid	0	2.39		0	0.95		0		
Nitrogen fractionization:									
% Total Nitrogen	1.55	1.54		1.52	1.51		1.21	1.55	
% Crude Protein (N x 6.25)	9.69	9.63		9.50	9.44		7.56	9.68	
% Water Soluble N	0.263	0.617	+ 234.6%	0.201	0.457	+ 227.4%	0.176	0.404	+ 229.5%
as % of total N	15.22	40.06		13.22	30.26		14.55	26.06	
% Water Insoluble N (by difference)	1.287	0.923		1.319	1.053		1.034	1.146	
as % of total N	83.03	59.94		86.78	69.74		85.45	73.94	
% Soluble NPN	0.213	0.604	+ 283.6%	0.189	0.423	+ 223.8%	0.149	0.385	+ 258.4%
as % of total N	13.74	39.22		12.43	28.01		12.31	24.84	
as % of Water Soluble N	80.99	97.89		94.03	92.56		84.66	95.30	
% NH_3 - N	0.038	0.102	+ 268.4%	0.029	0.107	+ 369.0%	0.014	0.143	+1021.4%
as % of NPN	17.84	16.89		15.34	25.30		9.40	37.14	

TABLE 14

Silage Parameters Relative to Stage of Maturity and Fineness of Chop Used in Experiment 2 - Feeding Trial 1

	Sept.		Oct.		Nov.		Treatment Means				
	Fine	Med.	Fine	Med.	Fine	Med.	Sept.	Oct.	Nov.	Fine	Med.
Silo Number	3	4	1	2	11	10					
% Dry Matter	30.44	27.87	49.62	45.38	60.70	58.19	28.21	48.15	59.55	46.92	43.81
pH	3.78	3.70	4.18	4.60	5.15	5.45	3.74	4.39	5.30	4.37	4.58
	All values expressed as a per cent of dry matter										
% Lactic Acid	5.29	6.41	2.19	0.83	0.52	0.26	5.85	1.51	0.39	2.67	2.50
% Acetic Acid	2.35	2.43	1.01	0.89	0.77	0.34	2.39	0.95	0.56	1.38	1.22

TABLE 15

Silage Parameters Relative to Stage of Maturity and Fineness of Chop
Used in Experiment 2 - Feeding Trial 1

	Sept.		Oct.		Nov.		Treatment Means				
	Fine	Med.	Fine	Med.	Fine	Med.	Sept.	Oct.	Nov.	Fine	Med.
Silo Number	3	4	1	2	11	10					
Nitrogen fractionization			All values expressed as a per cent of dry matter								
% Total N	1.49	1.59	1.45	1.57	1.51	1.59	1.54	1.51	1.55	1.48	1.59
% Crude Protein (N x 6.25)	9.31	9.94	9.06	9.81	9.44	9.94	9.63	9.44	9.69	9.25	9.94
% H_2O Soluble N	0.560	0.674	0.448	0.466	0.399	0.410	0.617	0.457	0.405	0.469	0.517
as % of Total N	37.58	42.38	30.89	29.68	26.42	25.78	40.06	30.26	26.12	31.69	32.52
% H_2O Insoluble N (by difference)	0.930	0.916	1.002	1.104	1.111	1.180	0.923	1.053	1.145	1.011	1.073
as % of Total N	62.42	57.61	69.10	70.32	73.58	74.21	59.94	69.74	73.87	68.31	67.48
% Soluble NPN	0.556	0.653	0.433	0.414	0.384	0.387	0.605	0.424	0.386	0.458	0.485
as % of Total N	37.31	41.06	29.86	26.36	25.43	24.33	39.29	28.08	24.90	30.95	30.50
as % of H_2O Sol. N	99.28	96.88	96.65	88.84	96.24	94.39	98.06	92.78	95.31	97.63	93.81
% NH_3 - N	0.096	0.107	0.112	0.101	0.142	0.144	0.102	0.107	0.143	0.117	0.117
as % of NPN	17.27	16.39	25.87	24.40	36.98	37.21	16.86	25.24	37.05	25.55	24.12

All other factors analyzed with the exception of total nitrogen showed the same trends which occurred in Experiment 1 and previously discussed. Total nitrogen remained constant (Table 15) across all harvest dates instead of declining as the corn plant matured as in Experiment 1. There were no significant differences in any fermentation parameters between the fine and medium chop. Difference between mean values for harvest dates, with the exception of total nitrogen, were significant ($P < .05$); however, none of the differences between fine and medium chop proved to be significant.

Dry Matter Yield and Silo Storage Requirements. As shown in Table 16, dry matter yield per acre was decreased 10.6% by delaying the harvest 34 days from mid-September to mid-October (5.11 tons vs. 4.57 tons). The trend continued through the November harvest with an additional 11.1% decrease in yield when harvest was delayed 28 days from mid-October to mid-November (4.57 tons vs. 4.06 tons). This gave a combined decrease of 20.5% when harvest was delayed 62 days from mid-September to mid-November.

Most of the published data would indicate that corn silage dry matter yield per acre increases until dry matter content of the corn plant reaches approximately 35%. It then levels off for a few days and subsequently decreases at a rapid rate depending upon weather conditions (Johnson and McClure, 1968; Huber et al., 1968; Hanway, 1963, 1966; and Gordon, 1966). Since no harvests were made between the dry matter levels of 28% and 48%, maximum dry matter yield per acre was probably missed.

The effect of stage of maturity and fineness of chop on pounds of silage dry matter stored per cubic foot of silo capacity is shown in Table 17. It is interesting to note that in all cases, dry matter stored

TABLE 16

Effect of Stage of Maturity and Fineness of Chop on Dry Matter and Dry Matter Yield per Acre

Harvest Date	Degree of Chop	Av. DM (%)	Tons/Acre		% Change from	
			100% DM	30% DM	Sept. 13	Oct. 17
Sept. 13	Fine	30.44%	5.11T	17.03T		
	Medium	27.87%				
	Combined	28.21%				
Oct. 17	Fine	49.62%	4.57T	15.23T	-10.61%	
	Medium	45.38%				
	Combined	48.15%				
Nov. 14	Fine	60.70%	4.06T	13.53T	-20.53%	-11.09%
	Medium	58.19%				
	Combined	59.55%				

Note: The corn yield following the November harvest of silage amounted to 74.9 bu./acre of 85% DM corn. This was equivalent to 4.33 bu. shelled corn per ton of 30% DM silage for the September harvest, 4.92 for the October harvest and 5.53 for the November harvest.

TABLE 17

Effect of Stage of Maturity and Fineness of Chop on Silo Storage Requirements

Harvest Date	Degree of Chop	Lbs. of DM per cu. ft. silage	% Change between fine and coarse chop	% Change from	
				Sept. 13	Oct. 17
Sept. 13	Fine	13.40			
	Coarse	11.14	-16.9%		
Oct. 17	Fine	11.99			
	Coarse	9.96	-16.9%	-10.6%	
Nov. 14	Fine 1	11.93			
	Coarse 1	10.97	- 8.0%	- 6.7%	+ 4.1%

1 Water added to silage with one-inch hose connected to blower.

per cubic foot of silo capacity was greater for the fine chopped silage than the medium chopped silage. The difference was 16.9% in the September harvested silage, 16.9% for the October harvested silage and 8.0% for the November harvested silage.

Likewise, density of the combined fine and medium chopped silage harvested in September was 10.6% greater than October harvested silage and 6.7% greater than November harvested silage. Density of the November harvested silage was actually 4.1% greater than the October harvested silage. A large volume of water was added during the silo filling process to the November harvested silage. This, no doubt, is responsible for the increased density. No water was used in the September and October harvests.

No other authors reviewed have published data relating silage maturity and fineness of chop to silo storage capacity.

Feeding Value of Mid-September vs. Mid-October vs. Mid-November Harvested Corn Silage. Pooled results of the effect of harvest date on rate of gain and feed efficiency are shown in Table 18 and its effect on carcass quality in Table 19. Complete performance of all lots of cattle are shown in Appendix III. The cattle fed mid-September harvested silage produced significantly ($P < .04$) faster average daily gains (0.17 lb. daily) than the cattle fed mid-October harvested silage (2.87 lb. vs. 2.70 lb.), but the rate of gain for the group fed the October harvested silage was not significantly different from the group fed November harvested silage. Daily dry matter consumption was highest for the cattle fed November harvested silage (2.38% of body weight daily for cattle fed September harvested silage vs. 2.40% for October, vs. 2.46% for November.)

Published reports do not establish a clear cut relationship between corn silage maturity and beef cattle gains. Zimmerman, Newmann,

TABLE 18

Effect of Harvest Date on Rate of Gain and Feed Efficiency
September vs. October vs. November Harvests
(January 13, 1967 to July 12, 1967)

180 Days on Experiment Lot Numbers	Sept. Harvest 14, 21 20, 22	Oct. Harvest 15, 17 23, 19	Nov. Harvest 16, 24 13, 18
No. of animals	36	36	36
Av. initial weight, lbs.	538	538	538
Av. final weight, lbs.	1053	1024	1031
Av. daily gain, lbs.	2.87a	2.70b	2.74ab
Av. daily ration, lbs.			
Corn silage fed	33.11	19.59	17.82
Corn silage consumed 1	32.86	19.23	17.26
85% DM shelled corn	7.26	7.08	6.96
Protein supplement	0.99	0.97	0.96
TOTAL 85% DM basis	18.98	18.71	19.28
Feed consumed per cwt. gain, lbs.			
TOTAL 85% DM basis	661	693	706
Daily feed consumed per 100 lbs. body weight, lbs.			
TOTAL 85% DM basis	2.38	2.40	2.46
Concentrates 2	1.04	1.03	1.01
Roughage	1.34	1.37	1.45
Concentrate:Roughage Ratio 3	66:34	66:34	66:34
Feed cost per cwt. gain 4	$11.27	$11.77	$11.80
Live selling price per cwt.	$25.95	$25.13	$24.93

1 Corn silage consumed - does not include the portion of silage fed which was refused by the steers.
2 Does not contain grain content of corn silage.
3 Does contain grain content of corn silage.
4 Feed prices used: Corn silage - $7.50 per ton on 30% DM basis; Shelled corn - $1.20 per bushel; MSU-64 supplement - $5.50 per cwt.

Values with no subscript or having the same subscript are not significantly different. A = ($P < .01$), a = ($P < .05$).

TABLE 19

Effect of Harvest Date on Carcass Quality
September vs. October vs. November Harvests
(January 13, 1967 to July 12, 1967)

180 Days on Experiment Lot Numbers	Sept. Harvest 14, 21 20, 22	Oct. Harvest 15, 17 23, 19	Nov. Harvest 16, 24 13, 18
Carcass evaluation:			
Carcass grade 5	12.07	11.90	11.72
Marbling score 6	16.05	14.99	14.50
Fat thickness, 13th rib, inches	0.84a	0.72	0.66
Rib eye area, sq. inches	11.70	11.44	11.67
% Kidney, heart and pelvic fat	2.95a	2.49	2.49
Cutability 7	48.02	49.03	49.56
Cold carcass weight, lbs.	623a	586	588
Dressing per cent	58.74a	57.40	56.95
Carcass price per cwt.	$44.17	$43.78	$43.78

5 Carcass grade values: 7 = Standard; 10 = Good; 13 = Choice; 16 = Prime.
6 Marbling values: 11 = Slight; 14 = Small; 17 = Modest; 20 = Moderate; 23 = Slightly Abundant.
7 Per cent boneless, trimmed, retail cuts.

Values with no subscript or having the same subscript are not significantly different. A = ($P < .01$), a = ($P < .05$).

Hinds and Lamb (1965) reported a significant increase in daily gain when the cattle were fed a silage which was 34% dry matter vs. silages of 27% and 40% dry matter. Burroughs and Topel (1969) using silages of 32% and 44% dry matter found no difference in average daily gain.

Although average daily gain for the cattle fed November harvested silage was intermediate between the September and October groups, average daily feed consumption was highest. Therefore, feed required per cwt. of gain was greatest for the November group, least for the September group and intermediate for the October group (706 lb. vs. 661 lb. vs. 693 lb., respectively).

The increase in daily dry matter intake in this trial is consistent with the published literature (Bryant et al., 1966; Bryant, Huber and Blaser, 1965; Huber, Graff and Engel, 1965; Marshall, Norden, Ross and Myers, 1966 and Owen et al., 1967). Johnson and Cook (1970) reported a significant positive correlation coefficient of 0.65 between daily dry matter intake and silage dry matter. Klosterman (1963) also reported increased dry matter intake but added that feed efficiency was significantly poorer in the more mature silage. Klosterman's results are in complete agreement with that presented in this study. Improvement in feed efficiency for lower dry matter silages has also been reported by Fowler et al. (1968), Klosterman (1964), and Burroughs and Topel (1969).

Cattle fed September harvested silage produced superior carcasses to the October and November silage fed groups. Differences in per cent boneless, trimmed, retail cuts; fat thickness; per cent kidney, heart and pelvic fat; cold carcass weight and dressing per cent were significant at the 1% level of probability.

Fine vs. Medium Chop Silage. Pooled results of all lots of cattle fed fine and medium chop silage (September, October and November) are shown in Table 20 and 21.

Cattle fed the fine chop silage gained an average of 0.09 lb. more per day than those fed the medium chopped silage (2.81 lb. vs 2.72 lb.). This difference approached significance ($P < 0.10$). Likewise, daily dry matter consumption was slightly greater for the fine chop fed group than the medium chop group (2.44% of body weight daily vs. 2.39%). For all other comparisons, differences were small and nonsignificant.

It is apparent from examination of the data in Tables 22 and 23 that fineness of chop had little effect on cattle performance for cattle fed the September harvested silage. However, a difference of 0.15 lb. daily favoring fine chop existed for the October harvested silage and a difference of 0.09 lb. daily favoring the fine chop silage existed for cattle fed the November harvested silage. These data indicate that fineness of chop is more important in silages harvested at dry matter ranges above 35% to 40% than silages harvested at lower dry matters.

Huber *et al.* (1966) reported no significant difference in dairy heifer performance when silages of varying degrees of chop were fed.

Reground vs. As Ensiled Feeding. Combined results of this comparison are shown in Tables 24 and 25. Average daily gain was almost identical for the fine chop silage when fed as ensiled and reground. However, a small difference favoring regrinding existed in pounds of dry matter required to produce 100 lb. of gain (680 lb. vs. 703 lb.). Likewise, no difference existed in average daily gain for the cattle fed the medium chop silage when fed as ensiled and reground; but again, feed efficiency favored the reground group (687 lb. vs. 725 lb.). Since, in both cases,

TABLE 20

Effect of Fine vs. Medium Chopped Corn Silage
on Rate of Gain and Feed Efficiency
(January 13, 1967 to July 12, 1967)

180 Days on Experiment	Fine Chop	Medium Chop
Lot Numbers	14, 21, 15 17, 16, 24	20, 22, 23 19, 13, 18
No. of animals	54	54
Av. initial weight, lbs.	538	538
Av. final weight, lbs.	1044	1028
Av. daily gain, lbs.	2.81	2.72
Av. daily ration, lbs.		
Corn silage fed	23.33	23.69
Corn silage consumed 1	23.08	23.15
85% DM shelled corn	7.18	7.02
Protein supplement	0.97	0.98
TOTAL 85% DM basis	19.29	18.69
Feed consumed per cwt. gain, lbs.		
TOTAL 85% DM basis	686	687
Daily feed consumed per 100 lbs. body weight, lbs.		
TOTAL 85% DM basis	2.44	2.39
Concentrates 2	1.03	1.02
Roughage	1.41	1.37
Concentrate:Roughage Ratio 3	66:34	66:34
Feed cost per cwt. gain 4	$11.57	$11.67
Selling price per cwt.	$25.39	$25.34

1 Corn silage consumed - does not include the portion of silage fed which was refused by the Steers.
2 Does not contain grain content of corn silage.
3 Does contain grain content of corn silage.
4 Feed prices used: Corn silage - $7.50 per ton on 30% DM basis; Shelled corn - $1.20 per bushel; MSU-64 supplement - $5.50 per cwt.

Values with no subscript or having the same subscript are not significantly different. A = ($P < .01$), a = ($P < .05$).

TABLE 21

Effect of Fine vs. Medium Chopped Corn Silage on Carcass Quality (January 13, 1967 to July 12, 1967)

180 Days on Experiment	Fine Chop	Medium Chop
Lot Numbers	14, 21, 15 17, 16, 24	20, 22, 23 19, 13, 18
Carcass evaluation:		
Carcass grade 5	12.14	11.92
Marbling score 6	15.34	15.02
Fat thickness, 13th rib, inches	0.76	0.72
Rib eye area, sq. inches	11.64	11.56
% Kidney, heart and pelvic fat	2.67	2.61
Cutability 7	48.71	49.03
Cold carcass weight, lbs.	604	594
Dressing per cent	57.71	57.69
Carcass price per cwt.	$44.00	$43.82

5 Carcass grade values: 7 = Standard; 10 = Good; 13 = Choice; 16 = Prime.

6 Marbling values: 11 = Slight; 14 = Small; 17 = Modest; 20 = Moderate; 23 = Slightly Abundant.

7 Per cent boneless, trimmed, retail cuts.

Values with no subscript or having the same subscript are not significantly different. A = $(P < .01)$, a = $(P < .05)$.

TABLE 22

Effect of Fine vs. Medium Chopped Corn Silage
Within Harvest Dates
on Rate of Gain and Feed Efficiency
(January 13, 1967 to July 12, 1967)

180 Days on Experiment	Sept.		Oct.		Nov.	
	Fine	Medium	Fine	Medium	Fine	Medium
Lot Numbers	14, 21	20, 22	15, 17	23, 19	16, 24	13, 18
No. of animals	18	18	18	18	18	18
Av. initial wt., lbs.	539	538	539	538	538	539
Av. final wt., lbs.	1057	1049	1038	1011	1038	1024
Av. daily gain, lbs.	2.89	2.85	2.78	2.63	2.78	2.69
Av. daily ration, lbs.						
Corn silage fed	33.18	33.05	19.39	19.70	17.41	18.24
Corn silage consumed 1	33.00	32.71	19.18	19.29	17.06	17.46
85% DM shelled corn	7.34	7.18	7.12	7.04	7.08	6.84
Protein supplement	0.99	0.99	0.98	0.98	0.96	0.97
TOTAL 85% DM basis	19.45	18.50	18.97	18.45	19.46	19.11
Feed consumed per cwt. gain, lbs.						
TOTAL 85% DM basis	678	650	689	703	702	710
Daily feed consumed per 100 lbs. body wt., lbs.						
TOTAL 85% DM basis	2.44	2.33	2.41	2.38	2.47	2.45
Concentrates 2	1.05	1.03	1.03	1.03	1.02	1.00
Roughage	1.40	1.30	1.38	1.35	1.45	1.45
Concentrate:Roughage Ratio 3	66:34	67:33	66:34	66:34	65:35	65:35
Feed cost per cwt. gain 4	$11.42	$11.17	$11.59	$12.02	$11.74	$11.84
Selling price per cwt.	$25.99	$25.90	$25.17	$25.14	$24.92	$24.96

1 Corn silage consumed - does not include the portion of silage fed which was refused by the steers.
2 Does not contain grain content of corn silage.
3 Does contain grain content of corn silage.
4 Feed prices used: Corn silage - $7.50 per ton on 30% DM basis; Shelled corn - $1.20 per bushel; MSU-64 supplement - $5.50 per cwt.

Values with no subscript or having the same subscript are not significantly different. A = ($P < .01$), a = ($P < .05$).

TABLE 23

Effect of Fine vs. Medium Chopped Corn Silage
Within Harvest Dates
on Carcass Quality
(January 13, 1967 to July 12, 1967)

180 Days on Experiment	Sept.		Oct.		Nov.	
	Fine	Medium	Fine	Medium	Fine	Medium
Lot Numbers	14, 21	20, 22	15, 17	23, 19	16, 24	13, 18
Carcass evaluation:						
Carcass grade [5]	12.57	12.37	11.94	11.86	11.77	11.67
Marbling score [6]	16.19	15.91	15.06	14.92	14.55	14.45
Fat thickness, 13th rib, inches	0.81	0.87	0.77	0.67	0.66	0.66
Rib eye area, sq. inches	11.85	11.55	11.48	11.40	12.19	12.33
% Kidney, heart, and pelvic fat	2.94	2.94	2.50	2.48	2.46	2.50
Cutability [7]	48.27	47.81	49.08	49.03	49.63	49.54
Cold carcass wt., lbs.	625	621	594	579	592	582
Dressing per cent	58.77	58.71	57.33	57.49	56.90	57.02
Carcass price	$44.22	$44.12	$43.91	$43.73	$43.79	$43.77

5 Carcass grade values : 7 = Standard; 10 = Good; 13 = Choice; 16 = Prime.
6 Marbling values: 11 = Slight; 14 = Small; 17 = Modest; 20 = Moderate; 23 = Slightly Abundant.
7 Per cent boneless, trimmed, retail cuts.

Values with no subscript or having the same subscript are not significantly different. A = $(P < .01)$, a = $(P < .05)$.

TABLE 24

Effect of As Ensiled vs. Regrinding of Corn Silage on Rate of Gain and Feed Efficiency (January 13, 1967 to July 12, 1967)

180 Days on Experiment	Fine Chop		Medium Chop	
	As Ensiled	Reground	As Ensiled	Reground
Lot Numbers	15 & 16	17 & 24	23 & 13	19 & 18
No. of animals	18	18	18	18
Av. initial weight, lbs.	539	537	538	539
Av. final weight, lbs.	1037	1039	1017	1018
Av. daily gain, lbs.	2.77	2.79	2.66	2.66
Av. daily ration, lbs.				
Corn silage fed	18.68	18.12	19.63	18.40
Corn silage consumed 1	18.25	17.91	18.58	18.17
85% DM shelled corn	7.18	7.01	7.11	6.77
Protein supplement	0.98	0.96	0.98	0.96
TOTAL 85% DM basis	19.47	18.96	19.29	18.28
Feed consumed per cwt. gain, lbs.				
TOTAL 85% DM basis	703	680	725	687
Daily feed consumed per 100 lbs. body weight, lbs.				
TOTAL 85% DM basis	2.47	2.40	2.48	2.35
Concentrates 2	1.03	1.01	1.04	0.99
Roughage	1.44	1.39	1.44	1.36
Concentrate:Roughage Ratio 3	65:35	65:35	65:35	65:35
Feed cost per cwt. gain 4	$11.82	$11.44	$12.21	$11.64
Selling price per cwt.	$25.25	$25.53	$25.28	$25.28

1 Corn silage consumed - does not include the portion of silage fed which was refused by the steers.

2 Does not contain grain content of corn silage.

3 Does contain grain content of corn silage.

4 Feed prices used: Corn silage - $7.50 per ton on 30% DM basis; Shelled corn - $1.20 per bushel; MSU-64 supplement - $5.50 per cwt.

Values with no subscript or having the same subscript are not significantly different. A = $(P < .01)$, a = $(P < .05)$.

TABLE 25

Effect of As Ensiled vs. Regrinding of Corn Silage on Carcass Quality (January 13, 1967 to July 12, 1967)

180 Days on Experiment	Fine Chop		Medium Chop	
	As Ensiled	Reground	As Ensiled	Reground
Lot Numbers	15 & 16	17 & 24	23 & 13	19 & 18
Carcass evaluation:				
Carcass grade 5	12.28	12.00	11.88	11.96
Marbling score 6	15.65	15.03	15.17	14.87
Fat thickness, 13th rib, inches	0.73	0.79	0.67	0.77
Rib eye area, sq. inches	11.52	11.76	11.46	11.66
% Kidney, heart and pelvic fat	2.75	2.59	2.61	2.61
Cutability 7	48.76	48.67	49.10	48.80
Cold carcass weight, lbs.	609	609	592	596
Dressing per cent	57.33	58.09	57.63	57.75
Carcass price	$44.05	$43.95	$43.87	$43.77

5 Carcass grade values: 7 = Standard; 10 = Good; 13 = Choice: 16 = Prime.
6 Marbling values: 11 = Slight; 14 = Small; 17 = Modest; 20 = Moderate; 23 = Slightly Abundant
7 Per cent boneless, trimmed, retail cuts.

Values with no subscript or having the same subscript are not significantly different A = ($P < .01$), a = ($P < .05$).

feeding reground silage was more efficient than feeding as ensiled silage, it would imply that the differences were due to a difference in physical particle size, rather than a difference in fermentation.

Experiment 3 - Feeding Trial 2

Table 26 shows the weather conditions during the harvest period. There was no frost prior to the September 18, 1967 harvest date. Between September 22 (conclusion of the September harvest) and October 2 (beginning of the October harvest) a light frost was encountered on September 23 (32^{o} F) followed by high winds on September 26 (18 mph). On October 1, the day prior to harvest, a second light frost was encountered (32^{o} F). Visual observation showed the plant to have suffered little discoloration and no loss of leaves. Between October 3 (conclusion of the second harvest) and October 19 (beginning of the third harvest) no high winds and only one fairly heavy frost on October 19 were encountered. The corn plant retained approximately 30% of its green color and about 90% of the leaves were still attached to the plant. The amount of frost and loss of leaves occurring prior to October 19 was negligible in comparison with results obtained in the 1966 harvest and reported previously.

Characterization of silage used in this trial is shown in Tables 27 and 28. The September harvested silage averaged 30.7% dry matter and the October harvested silage averaged 43.3% dry matter. As in the previous experiment, the dry matter was lower in the medium chop than in the fine chop. This substantiates the previous finding that more water evaporated from the finely chopped material between chopping and sampling. All other parameters shown in Tables 27, 28, and 29 are similar to and trends are of the same magnitude as reported in Experiments 1 and 2. A decrease in

TABLE 26

Weather Data During 1967 Harvest 1

Days Temperature Dropped Below Freezing		Wind
Date 2	Temperature	Mph High During Period
Sept. 23	32^{o}	
Sept. 26		18.0
Oct. 1	32^{o}	
Oct. 19	31^{o}	
Oct. 20	30^{o}	
Oct. 21	29^{o}	
Oct. 22	23^{o}	

1 Weather data reported as recorded at the U. S. Weather Bureau, Capital City Airport, Lansing, Michigan.

2 Dates not listed are days during which the temperature did not fall below freezing.

TABLE 27

Mean Silage Parameters Relative to Stage of Maturity and Fineness of Chop
Used in Experiment 3 - Feeding Trial 2

	September		October		Treatment Means			
	Fine	Med.	Fine	Med.	Sept.	Oct.	Fine	Med.
Silo Number	3	4	1	2				
% Dry Matter	31.70	30.20	46.30	40.30	30.70	43.30	39.00	35.25
pH	3.88	3.79	3.95	4.05	3.74	4.00	3.92	3.92
All values expressed as a per cent of dry matter								
% Lactic Acid	4.83	5.86	2.59	3.21	5.35	2.90	3.71	4.54
% Acetic Acid	2.24	1.72	0.73	0.90	1.98	0.82	1.49	1.31

TABLE 28

TABLE 28

Mean Silage Parameters Relative to Stage of Maturity and Fineness of Chop
Used in Experiment 3 - Feeding Trial 2

	September		October		Treatment Means			
	Fine	Med.	Fine	Med.	Sept.	Oct.	Fine	Med.
	3	4	1	2				
Nitrogen fractionization	All values expressed as a per cent of dry matter							
% Total N	1.15	1.28	1.11	1.36	1.22	1.24	1.13	1.32
% Crude Protein (N x 6.25)	7.19	8.00	6.94	8.50	7.63	7.75	7.07	8.25
% H_2O Soluble N	0.488	0.556	0.478	0.536	0.522	0.507	0.483	0.546
as % of total N	42.43	43.44	43.06	39.41	42.79	40.89	42.75	41.43
% H_2O Insoluble N (by difference)	0.662	0.724	0.632	0.824	0.698	0.733	0.647	0.774
as % of total N	57.57	56.56	56.94	60.59	57.21	59.11	57.26	58.58
% Soluble NPN	0.391	0.394	0.366	0.391	0.393	0.379	0.379	0.393
as % of total N	34.00	30.78	32.97	28.75	32.21	30.56	33.49	29.77
as % of H_2O Sol. N	80.12	70.86	76.57	72.95	75.29	74.75	78.35	71.91
% NH_3N	0.049	0.054	0.051	0.060	0.052	0.056	0.050	0.057
as % of NPN	12.53	13.71	13.93	15.35	13.23	14.78	13.23	14.53

TABLE 29

Mean Silage Parameters Relating Fresh and Ensiled Material
Used in Experiment 3 - Feeding Trial 2

	September			October		
	Fresh	Ensiled	Change	Fresh	Ensiled	Change
% Dry Matter		30.70			43.30	
pH	5.70	3.74		5.22	4.00	
All values expressed on a dry matter basis						
% Lactic Acid	0	5.35		0	2.90	
% Acetic Acid	0	1.98		0	0.82	
Nitrogen fractionization						
% Total Nitrogen	1.44	1.22		1.61	1.24	
% Crude Protein (N x 6.25)	9.00	7.50		10.06	7.75	
% Water Soluble N	0.357	0.522	+146.22%	0.222	0.507	+228.38%
as % of Total N	24.79	42.79		13.79	40.89	
% Water Insoluble N (by difference)	1.083	0.698		1.388	0.733	
as % of Total N	75.21	57.21		86.21	59.11	
% Soluble NPN	0.176	0.393	+223.30%	0.201	0.379	+188.56%
as % of Total N	12.22	32.21		12.48	30.56	
as % of Water Soluble N	49.30	75.29		90.54	74.75	
% NH_3 - N	0.013	0.052	+400.00%	0.016	0.056	+350.00%
as % of NPN	7.38	13.23		7.96	14.78	

total nitrogen was not experienced in these harvests as was the case in Experiment 2, both differing from results obtained in Experiment 1.

Dry Matter Yield per Acre and Silo Storage Capacity. Average per cent dry matter of the silage and dry matter yield per acre for each harvest date are shown in Table 30. Dry matter yield per acre increased 4.0% (5.64 tons vs. 5.86 tons) between the September 18 and October 3 harvests and decreased 6.1% (5.86 tons vs. 5.56 tons) between the October 3 and October 19 harvest. These results are consistent with results obtained during the 1966 harvest and reported previously in Experiment 2. As concluded by Huber et al. (1968), corn silage dry matter yield per acre appears to be maximized at about 35% dry matter and little is to be gained by purposely delaying harvest beyond this point.

The effect of stage of maturity and fineness of chop on silo storage capacity is shown in Table 31.

The length of time needed to fill each silo varied slightly, due to weather conditions, available labor, etc. For the mid-September harvest, the silo filled with fine chop silage required two days, whereas three days were required to fill the silo with medium chop silage. In mid-October, one day and two days were required for filling the silos with fine and medium chop silages, respectively. In no case were silos refilled after initial filling. These time periods are presented due to the possible effect of filling time on the silo storage capacity.

Dry matter stored per cubic foot of silo capacity was increased 5.56% (11.93 lb. vs. 12.16 lb.) by delaying harvest from mid-September (30.7% dry matter) to mid-October (43.3% dry matter). These results do not agree with results obtained in Experiment 2 where dry matter stored per

TABLE 30

Effect of Stage of Maturity on Dry Matter Yield Per Acre

Harvest Date	Degree of Chop	Per cent DM	Tons/Acre		% Change From Sept. 18
			100% DM	30% DM	
Sept. 18-22	Fine	31.7%			
	Medium	30.2%			
	Combined	30.7%	5.64T	18.8	
Oct. 2-4 1	Fine	34.7%	5.86T	19.5	+4.0%
Oct. 19-21	Fine	46.3%			
	Medium	40.3%			
	Combined	43.3%	5.56T	18.5	-1.4%

1 Harvested for Dairy Department

TABLE 31

Effect of Stage of Maturity and Fineness of Chop on Silo Storage Requirements

Harvest Date	Degree of Chop	% DM	Lbs. of DM per cu. ft. of silo	% change between fine & medium chop	% Change From Sept. 18
Mid-September					
Silo 3	Fine	31.1%	12.32		
Silo 4	Medium	30.2%	11.55		
	Average	30.7%	11.93	-6.25%	
Mid-October					
Silo 1	Fine	46.3%	13.15		
Silo 2	Medium	40.3%	12.13		
	Average	43.3%	12.64	-7.77%	+5.56%

cubic foot of silo capacity was reduced 11% by delaying harvest from mid-September (28% dry matter) to mid-October (48% dry matter) and further reduced 7% by delaying harvest to mid-November (60% dry matter). This discrepancy may be partially explained by the 1966 harvest requiring one day to fill each silo and the 1967 harvest requiring two to three days to fill each silo, and thus allowing more time for settling and compaction while filling.

The September harvested fine chop was 6.25% higher than the coarse chop in pounds of dry matter stored per cubic foot (12.32 lb. vs. 11.55 lb.). The same trend continued in the October harvest (a 7.77% advantage with the fine chop) due to the greater compaction of the finer chopped material (13.15 lb. vs. 12.13 lb. per cubic foot). These results are in agreement with similar results obtained during the 1966 harvest.

<u>Mid-September vs. Mid-October Harvested Corn Silage</u>. Pooled results of the effect of harvest date on rate of gain, feed efficiency and carcass quality are shown in Tables 32 and 33. Complete performance of all lots are shown in Appendix III. Cattle fed mid-September harvested silage gained significantly ($P < .05$) faster than cattle fed mid-October harvested silage (2.58 lb. vs. 2.46 lb.). Their higher rate of gain coupled with a slightly lower daily dry matter consumption (17.27 lb. vs. 17.62 lb.), resulted in a substantially lower feed requirement per cwt. of gain (660 lb. vs. 716 lb.). These factors were the basis for the lower cost of gain shown for cattle fed the mid-September harvested silage ($11.58 vs. $12.39 per cwt. gain). All carcass traits favored the cattle fed the September harvested silage; however, these differences were small and non-significant. These results are in complete agreement with the results previously reported in Experiment 2.

TABLE 32

Effect of September vs. October Harvested Corn Silage
on Rate of Gain and Feed Efficiency
(November 17, 1967 to July 1, 1968) 1

214 Days on Experiment Lot Numbers	September Harvest 1, 2, 8, 9, 10, 12, 14, 15	October Harvest 3, 4, 5, 6, 7, 11, 13, 16
No. of animals	64	64
Av. initial weight, lbs.	478	478
Av. final weight, lbs.	1031	1004
Av daily gain, lbs.	2.58a	2.46
Av. daily ration, lbs.		
Corn silage fed	38.64	28.23
85% DM shelled corn	3.11	3.11
Protein supplement	0.98	0.98
TOTAL 85% DM basis	17.27	17.62
Feed consumed per 100 lbs. gain, lbs.	669	716
Daily feed consumed per 100 lbs. body weight, lbs.		
TOTAL 85% DM basis	2.29	2.38
Concentrates 2	1.24	1.28
Roughage	1.05	1.10
Concentrate:Roughage Ratio 3	24:76	23:77
Feed cost per 100 lbs. gain 4	$11.50	$12.39
Live selling price per cwt.	$25.30	$24.32

1 Performance data includes all animals in the treatment, whereas carcass data includes a random slaughter of one-half of the animals.
2 Does not contain grain content of corn silage.
3 Does contain grain content of corn silage.
4 Feed prices used: Corn silage - $7.50 per ton on 30% DM basis; Shelled corn - $1.20 per bushel; MSU-64 supplement - $5.50 per cwt.

Values with no subscript or having the same subscript are not significantly different. A = $(P < .01)$, a = $(P < .05)$.

TABLE 33

Effect of September vs. October Harvested Corn Silage
on Carcass Quality
(November 17, 1967 to July 1, 1968)

214 Days on Experiment Lot Numbers	September Harvest 1, 2, 8, 9, 10, 12 14, 15	October Harvest 3, 4, 5, 6, 7, 11, 13, 16
Carcass evaluation		
No. of animals	32	32
Carcass grade 5	11.34	10.88
Marbling score 6	14.19	14.19
Fat thickness, 13th rib, inches	0.60	0.72
Ribeye area, sq. inches	11.18	11.02
% Kidney, heart and pelvic fat	1.92	1.61
Cutability 7	49.65	49.15
Cold carcass weight, lbs.	605	587
Dressing per cent	58.50	56.64
Carcass price per cwt.	$43.25	$42.94
Beef produced per acre of corn fed, lbs.	1667	1558
Gross returns per acre of corn fed	$422.00	$377.00

5 Carcass grade values: 7 = Standard; 10 = Good; 13 = Choice; 16 = Prime
6 Marbling values: 11 = Slight; 14 = Small; 17 = Modest; 20 = Moderate; 23 = Slightly Abundant
7 Per cent boneless, trimmed, retail cuts

Values with no subscript or having the same subscript are not significantly different. A = ($P < .01$), a = ($P < .05$).

Fine vs. Medium Chop Silage. Pooled results of all fine and medium chop comparisons (September and October combined) are shown in Tables 34 and 35.

Cattle fed fine chop silage gained at a slightly faster rate than cattle fed medium chopped silage (2.55 lb. vs. 2.50 lb. daily). Likewise, dry matter consumption was slightly greater for the fine chop silage fed group than the medium chop silage fed group (2.39% of body weight daily vs. 2.28%). The cattle fed the fine chop silage produced significantly higher grading carcasses (11.41 vs. 10.81) which resulted in a significantly ($P < .05$) higher carcass price ($43.30 vs. $42.89 per cwt.). For all other comparisons, differences were small and nonsignificant. Again, results are in agreement with results reported in Experiment 2.

Experiment 4 - Metabolic Study

Rumen pH and VFA Concentrations. Results of this comparison are shown in Table 36.

Neither stage of maturity nor fineness of chop significantly influenced mean rumen pH (Table 36). The mean rumen pH for the September harvested silage was 6.12 and for the October harvest, 6.17. The fine chopped silage produced a mean rumen pH of 6.16 while the medium chopped silage produced a mean of 6.13.

Rumen pH is primarily due to the concentration of volatile fatty acids in the rumen, which can occur either by ingestion of feedstuffs containing volatile fatty acids or from rumen microbial fermentation. Rumen pH values for the sheep fed these silages relative to time after feeding (Table 36) exhibit a normal pattern (Fenner et al., 1967) of decreased pH during active fermentation up to two hours postfeeding and then increased pH as fermentation declines by six hours.

TABLE 34

Effect of Fine vs. Medium Chopped Corn Silage
on Rate of Gain and Feed Efficiency
(November 17, 1967 to July 1, 1968) 1

214 Days on Experiment Lot Numbers	Fine Chop 2, 3, 7, 10, 11, 12 14, 16	Medium Chop 1, 4, 5, 6, 8, 9, 13, 15
No. of animals	64	64
Av. initial weight, lbs.	477	479
Av. final weight, lbs.	1022	1014
Av. daily gain, lbs.	2.55	2.50
Av. daily ration, lbs.		
Corn silage fed	32.82	34.04
85% DM shelled corn	3.13	3.09
Protein supplement (MSU 64-670)	0.98	0.98
TOTAL 85% DM basis	17.90	16.99
Feed consumed per 100 lbs. gain, lbs.		
TOTAL 85% DM basis	702	680
Daily feed consumed per 100 lbs. body weight, lbs.		
TOTAL 85% DM basis	2.39	2.28
Concentrates 2	1.26	1.24
Roughage	1.13	1.04
Concentrate:Roughage Ratio 3	23:77	24:76
Feed cost per 100 lbs. gain 4	$12.17	$11.80
Live selling price per cwt.	$25.45	$24.17

1 Performance data includes all animals in the treatment, whereas carcass data includes a random slaughter of one-half of the animals. The remainder were fed to heavier slaughter weights.
2 Does not contain grain content of corn silage.
3 Does contain grain content of corn silage.
4 Feed prices used: Corn silage - $7.50 per ton on 30% DM basis; Shelled corn - $1.20 per bushel; MSU-64 supplement - $5.50 per cwt.

Values with no subscript or having the same subscript are not significantly different. A = ($P < .01$), a = ($P < .05$).

TABLE 35

Effect of Fine vs. Medium Chopped Corn Silage
on Carcass Quality
(November 17, 1967 to July 1, 1968)

214 Days on Experiment Lot Numbers	Fine Chop 2, 3, 7, 10, 11, 12, 14, 16	Medium Chop 1, 4, 5, 6, 8, 9, 13, 15
Carcass evaluation:		
No. of animals	32	32
Carcass grade 5	11.41a	10.81
Marbling score 6	14.13	14.25
Fat thickness, 13th rib, inches	0.60	0.73
Rib eye area, sq. inches	11.16	11.03
% Kidney, heart and pelvic fat	1.83	1.70
Cutability 7	49.72	49.15
Cold carcass weight, lbs.	599	593
Dressing per cent	58.78	56.36
Carcass price per cwt.	$43.30a	$42.89

5 Carcass grade values: 7 = Standard; 10 = Good; 13 = Choice; 16 = Prime.

6 Marbling values: 11 = Slight; 14 = Small; 17 = Modest; 20 = Moderate; 23 = Slightly Abundant

7 Per cent boneless, trimmed, retail cuts.

Values with no subscript or having the same subscript are not significantly different. A = $(P < .01)$, a = $(P < .05)$.

TABLE 36

Means of Rumen pH Values

Sampling Time	September		October		s.e.[1]	Treatment Means				s.e.[2]
	Fine	Medium	Fine	Medium		Sept.	Oct.	Fine	Medium	
T_0	6.60	6.35	6.40	6.40	0.1520	6.48	6.40	6.50	6.38	0.108
T_2	6.00	5.90	6.05	5.95	0.1061	5.95	6.00	6.03	5.93	0.075
T_4	6.05	6.00	6.00	6.00	0.056	6.03	6.00	6.03	6.00	0.040
T_6	6.05	6.10	6.20	6.25	0.035	6.07	6.23	6.13	6.18	0.025
$\bar{x}$	6.16	6.09	6.16	6.18	0.0746	6.12	6.17	6.16	6.13	0.053

[1]Two observations per mean
[2]Four observations per mean

Mean rumen volatile fatty acid concentrations for the various silages fed, expressed as μm of VFA per ml of rumen fluid and as molar per cent of the total VFA, are shown in Table 37. There were no significant differences between treatments. However, it is interesting to note the extremely high acetate:propionate ratio. This high ratio is not readily explainable and should be the subject of further investigation. Other authors have reported changes in this ratio due to various treatments; e.g. fineness of chop (Huber et al., 1966 and Miller et al., 1968), but none reviewed have reported ratios of this magnitude. Mahapatro and Leffel (1964) working with alfalfa and sudex silages at various dry matter levels reported that per cent of rumen acetate was lower and per cent rumen propionate was higher when dryer silages were fed. The reverse effect was reported by Hawkins (1969) working with alfalfa silages at varying dry matter levels.

Mean volatile fatty acid concentrations at the various sampling times are shown in Appendix III.

Dry Matter Intake and Dry Matter Digestibility. As shown in Table 38, lambs fed the fine chopped silage had a significantly higher dry matter intake than did the lambs fed the medium chopped silage ($P < .05$).

There was a small but nonsignificant difference in dry matter intake favoring the dryer silage as was the case in both feeding trials. As mentioned previously, this trend is supported by virtually all literature reviewed.

Dry matter digestibility was not significantly different for any of the treatments studied (Table 38). Thomson and Rogers (1968) reported differences which reduced digestibility with increasing dry matter content of silage and proposed the following regression equation:

TABLE 37

Mean Rumen Volatile Fatty Acid Concentrations and Molar Per Cent

	September		October		Treatment Means			
	Fine	Medium	Fine	Medium	Sept.	Oct.	Fine	Medium
Concentration (µm/ml)								
Acetic acid	19.50	20.57	22.43	17.04	20.03	19.73	20.96	18.80
Propionic acid	19.66	17.52	16.15	12.13	18.59	14.14	17.91	14.82
Isobutyric acid	1.30	0.94	1.45	1.20	1.12	1.32	1.37	0.82
Butyric acid	8.15	6.50	8.95	7.97	7.32	8.46	8.55	7.24
Total (µm/ml)	48.61	45.53	48.98	38.34	47.06	43.65	48.79	41.68
Molar Per Cent								
Acetic acid	40.11	45.18	45.79	44.44	42.56	45.20	42.96	45.11
Propionic acid	40.44	38.48	32.97	31.64	39.50	32.39	36.71	35.56
Isobutyric acid	2.67	2.06	2.96	3.13	2.38	3.02	2.81	1.97
Butyric acid	16.77	14.28	18.27	20.79	15.55	19.38	17.52	17.37
Acetate:Propionate Ratio	1.01	0.85	0.72	0.71	0.93	0.72	0.85	0.79

TABLE 38

Means for Sheep Parameters

	September		October		s.e.[1]	Treatment Means				s.e.[2]
	Fine	Medium	Fine	Medium		Sept.	Oct.	Fine	Medium	
Dry Matter intake (gm)	787.95	596.95	851.50	569.35	63.74	692.45	710.43	819.73*	583.15*	45.07
Fecal Dry Matter (gm)	289.20	185.20	268.20	172.45		237.20	220.33	278.70	178.83	
Dry Matter Digestibility %	63.29	68.69	68.36	69.93	2.496	65.94	69.14	65.78	69.31	1.765

[1]Two observations per mean
[2]Four observations per mean
*Significantly different ($P < .05$)

per cent dry matter digestibility = 71.21 - 0.14X

where X is the dry matter of the crop being ensiled. Applying this equation to these data, dry matter digestibility of the September harvested silage is calculated to be 66.91% and the October harvest is calculated to be 65.15%. Dry matter digestibility was actually 65.94% and 69.15% for the September and October harvests, respectively. This is very good agreement considering the degree of variability among the lambs used in this test. Similar results have been reported by Johnson et al. (1965, 1968).

Nitrogen Balance. Complete results of all nitrogen parameters are shown in Table 39. Virtually no difference existed in total nitrogen retention, nitrogen retained as a per cent of nitrogen intake and nitrogen retained as a per cent of nitrogen absorbed. Thus, all silages appeared to be equal in nitrogen utilization. Although apparent nitrogen digestibilities appear to be wide (50.12% vs. 55.57% for September and October harvested silage and 48.83% vs. 57.45% for fine and medium chopped silages) the differences did not prove to be significantly different.

The daily nitrogen intake (gm/day), as well as differences between treatments, parallels dry matter intake. Since nitrogen content as a per cent of dry matter did not differ greatly, this result would be expected.

Differences in fecal nitrogen (gm/day) were significant ($P < .05$) for the lambs fed the fine vs. medium chopped silage (4.82 gm vs. 3.51 gm). A difference of this magnitude would be expected due to the significant increase in dry matter intake between the lambs fed the fine and medium chopped silage. There was no significant difference in fecal nitrogen for the lambs fed the September vs. October harvested silages.

TABLE 39

Means for Nitrogen Balance Study

	September		October			Treatment Means				
	Fine	Medium	Fine	Medium	s.e.[1]	Sept.	Oct.	Fine	Medium	s.e.[2]
Nitrogen intake (gm/day)	9.09	7.94	9.75	8.57	0.804	8.52	9.16	9.42	8.25	0.569
Fecal nitrogen (gm/day)	4.75	3.76	4.89	3.26	0.319	4.25	4.07	4.82*	3.51*	0.226
Absorbed nitrogen (gm/day)	4.34	4.18	4.86	5.31		4.27	5.09	4.60	4.74	
Urinary nitrogen (gm/day)	2.30	2.79	2.46	2.85	0.315	2.55	2.65	2.38	2.82	0.223
Excreted nitrogen (gm/day)	7.05	6.55	7.35	6.11		6.80	6.72	7.20	6.33	
Retained nitrogen (gm/day)	2.04	1.39	2.41	2.46	0.724	1.72	2.43	2.22	1.93	0.512
Fecal N as % of N intake	52.26	47.36	50.15	38.04		49.88	44.43	51.17	42.55	
Urinary N as % of N intake	25.30	35.14	25.23	33.26		29.93	28.93	25.27	34.18	
Retained N as % of N intake	22.44	17.51	24.72	28.70		20.19	26.53	23.57	23.39	
Retained N as % of N absorbed	46.05	33.25	49.59	46.33		40.28	47.74	48.26	40.72	
Apparent N digestibility %	47.74	52.64	49.85	61.96		50.12	55.57	48.83	57.45	

*Significance = 0.015.
[1] Two observations per mean
[2] Four observations per mean

Correlation Coefficients. Correlation coefficients between all parameters studied in the metabolic trial are shown in Appendix IV.

As shown in Appendix IV, dry matter intake was negatively correlated with water soluble nitrogen ($r = -0.84$, $P < .01$), water soluble nonprotein nitrogen ($r = -0.66$, $P < .05$) and ammonia nitrogen ($r = -0.74$, $P < .05$). This would strongly indicate that these factors may be responsible, at least in part, for the low dry matter intake experienced with high moisture silages.

V. SUMMARY

In this dissertation, the results of four experiments are presented.

Experiment 1 - Fermentation Study. This study, utilizing experimental silos, involved 10 stages of corn silage maturity harvested at weekly intervals from September 3 to November 5 (22.1% dry matter to 48.3% dry matter). At each harvest, the silage was ensiled at four pressures (0, 2.5, 5 and 10 psi), and daily samples of each were analyzed.

Experiment 2 - Feeding Trial 1. This trial involved the harvesting of corn silage of 28.2% dry matter, 48.2% dry matter and 59.6% dry matter, and feeding this material to steer calves in a 180-day experiment. At each harvest, a fine and medium chop silage was harvested to study the effect of this parameter on silo fermentation, harvesting and animal performance.

Experiment 3 - Feeding Trial 2. This was conducted in the same manner as the first feeding trial, except that harvests were made at 30.7% dry matter and at 43.3% dry matter. The same fineness of chop parameters were reexamined.

Experiment 4 - Metabolic Study. This study was conducted to test the effect of silage maturity and fineness of chop on various metabolic parameters using eight mature fistulated lambs. Digestibility factors as well as rumen parameters were examined.

After reviewing all data presented in experiments one through four, it is obvious that the extensiveness of silage fermentation is significantly

and negatively correlated with dry matter content of the ensiled material within the range of 22.1% dry matter to 48.3% dry matter. Likewise, steer performance and efficiency of silage utilization is significantly and negatively correlated with dry matter content of silage within the range of 28.2% dry matter to 59.6% dry matter.

Therefore, from this relationship, it would appear that the more extensive the fermentation in silages, the more improvement is seen in animal performance. The question still remains, however, whether this improved animal performance is due to the quality of the plant at the lower dry matter and less mature stage of development, or if the silage fermentation is truly an advantageous factor in animal metabolism.

Assuming that ensiling is not a form of crop improvement, but rather a crop preservation method, then the process of fermentation should be considered as an aid in preservation and not a means of improving the nutritive value of the original material.

However, this fermentation should not decrease the value of the ensiled material. The end products of this fermentation, primarily lactic and acetic acids, are useful energy sources in the ruminant animal, and are not lost.

It has been conclusively shown in these data that the extent of fermentation decreases as dry matter increases. Hence, there was noted a decrease in lactic acid from a high of 5.82% of dry matter for the September 3 harvest to a low of 1.27% for the November 5 harvest. Likewise, acetic acid decreased from 1.89% of dry matter to 0.44% of dry matter for the September 3 and November 5 harvests, respectively. These are the major fermentation end products responsible for acidity of the ensiled mass which is a primary factor in the preservation of the crop. The level of lactic acid had no

detrimental effect on animal performance, as shown by the extremely low, nonsignificant correlation of -0.325 relating lactic acid levels and dry matter intake.

During an extensive fermentation, a significant degree of proteolysis occurs which produced relatively high levels of water soluble nitrogen and nonprotein nitrogen. These factors were most closely related to a decreased dry matter intake, as evidenced by the significant negative correlations between intake and water soluble nitrogen and nonprotein nitrogen ($r = -0.842$, $P < .01$; $r = -0.657$, $P < .05$, respectively). Ammonia nitrogen, although at extremely low levels, was also significantly and negatively correlated with dry matter intake ($r = -0.738$, $P < .05$).

It should be pointed out that nitrogen compounds added to silage as NPN; e.g. urea, do not give the decrease in dry matter intake unless added at extremely high levels, thereby producing an extensive fermentation (Henderson, unpublished data).

These data lead one to conclude that extensive fermentation is advantageous as an aid in preservation and the acids produced are of nutritive value, but some end products, namely the end products of the protein hydrolysis, result in decreased intakes. These decreases do not affect the efficiency of utilization of the ensiled material as shown in the feeding trials, but can influence average daily gain if extensive inhibition of dry matter intake occurs.

The literature suggests (section II) that the protein hydrolysis is due to the activity of plant enzymes in the early stages of silage fermentation. Working from the acceptance of this hypothesis, it would be interesting to further investigate the possibility of inhibiting this enzyme activity and, thereby, preventing the formation of these NPN compounds.

Mass density studies (Experiment 1) showed that when as low as 2.5 psi was applied to compress the mass, a normal fermentation proceeded. This was evidenced by the higher lactic acid in the silage fermented when under pressure.

The data presented in Experiments 2 and 3 show that the harvest of corn silage above 43% dry matter results in a reduced dry matter yield, increased silo storage requirements, and lowered animal performance. The reason for the decreased animal performance on the high dry matter silages is still not obvious. However, a possible explanation is that material which has undergone sufficient fermentation to produce relatively high concentrations of lactic acid results in more efficient gains. It should be pointed out that animal performance parameters were not highly correlated with lactate levels.

Hanway (1963, 1966), at the Iowa station, established that the corn plant has accumulated a maximum dry weight when it is approximately 35% dry matter (Figure 20). This is confirmed by other studies in which the maximum dry matter yield per acre was at this level (Huber *et al.*, 1968 and Johnson *et al.*, 1963). Johnson and McClure (1968) and Johnson *et al.* (1965) reported that maximum yield of digestible dry matter obtained was at lower dry matter levels (28% dry matter).

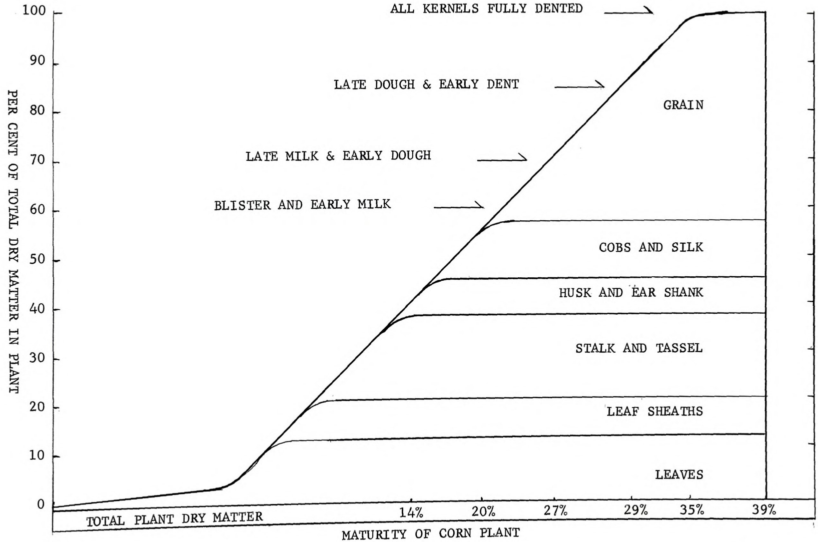
The data presented in this study clearly show that dry matter stored per cubic foot of silo space is reduced when dry matter content increases above approximately 31% dry matter. An average reduction of stored silage per unit space of 1% per week was found as harvest was delayed.

The steer performance reported in this study was also greatest at the early harvests. Average daily gain was significantly higher for the

FIGURE 20

FIGURE 20

EFFECT OF STAGE OF MATURITY OF CORN SILAGE ON TOTAL DRY MATTER ACCUMULATION IN THE CORN PLANT[1]



1 Hanway, 1966.

September harvested silage in both experiments. Feed efficiency (lb. of feed consumed per 100 cwt.) was also in favor of the steers fed the early harvested crop.

Performance and average yield factors, as well as the fermentation study (Experiment 1) which indicated a more desirable preservation strongly suggest that the delaying of harvest of corn silage beyond the 35% dry matter range should not be recommended.

Fineness of chop had a marked influence on the benefits derived from the silage crop. The more finely chopped material gave a more densely packed mass as shown by the greater number of pounds stored per cubic foot of silo space. Moreover, feed efficiency was consistently superior to the finely chopped material although differences were not significant.

The regrinding treatment showed that the changes in feed efficiency were due to the fineness of chop *per se*, and not an altered silo fermentation. It can also be concluded from these data that the importance of fineness of chop increases as maturity increases, or as dry matter of the plant increases. This necessity of having a finely chopped material at higher dry matters is, no doubt, related to the difficulty in packing these dryer materials.

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APPENDIX I

SAMPLE CALCULATION

SAMPLE CALCULATION

Experiment 1 - Silage Fermentation Study

Silage Dry Matter

Analysis of Variance

Source	d.f.	Mean Square	F	Approximate Level of Significance
Harvest date	9	277.5486	70.7312	<0.0005
Pressure	3	11.6683	2.9736	0.049
Error	27	3.9240		
Total	39			

$$\text{Standard Error} = \sqrt{\frac{3.924}{10}} = 0.627$$

Duncan New Multiple Range on Pressures

		P = 2	P = 3	P = 4
Critical Values	$(P < .01)$	2.45	2.55	2.62
	$(P < .05)$	1.82	1.90	1.96
Ranked means:	33.74	1.46		
	32.28	0.22	1.68	
	32.06	0.93	1.15	2.61*
	31.13			

APPENDIX II

DESIGN OF EXPERIMENTS

APPENDIX II - TABLE 1

Experiment 1 - Feeding Trial 1; Design of Experiment

(3 x 2 x 2 Factorial Design:
12 lots of cattle of 9 head each
= 108 steers.)

Lot No.	Harvest Date	Degree of Chop	Preparation of Feeding
14	September 15-16	Fine	as ensiled
21	September 15-16	Fine	as ensiled
20	September 13-14	Coarse	as ensiled
22	September 13-14	Coarse	as ensiled
15	October 17-18	Fine	as ensiled
17	October 17-18	Fine	reground
23	October 19-20	Coarse	as ensiled
19	October 19-20	Coarse	reground
16	November 15	Fine	as ensiled
24	November 15	Fine	reground
13	November 14	Coarse	as ensiled
18	November 14	Coarse	reground

APPENDIX II - TABLE 2

Experiment 2 - Feeding Trial II; Design of Experiment

(2 x 2 x 2 Replicated Factorial Design:
16 lots of cattle of 8 head each
= 128 steers.)

Lot No.	Harvest Date	Degree of Chop	Concentrate Level
2	Mid-September, 31% DM	Fine	0%
14	Mid-September, 31% DM	Fine	0%
10	Mid-September, 31% DM	Fine	1%
12	Mid-September, 31% DM	Fine	1%
8	Mid-September, 30% DM	Medium	0%
15	Mid-September, 30% DM	Medium	0%
1	Mid-September, 30% DM	Medium	1%
9	Mid-September, 30% DM	Medium	1%
11	Mid-October, 46% DM	Fine	0%
7	Mid-October, 46% DM	Fine	0%
3	Mid-October, 46% DM	Fine	1%
16	Mid-October, 46% DM	Fine	1%
4	Mid-October, 40% DM	Medium	0%
5	Mid-October, 40% DM	Medium	0%
6	Mid-October, 40% DM	Medium	1%
13	Mid-October, 40% DM	Medium	1%

APPENDIX II - TABLE 3

Metabolic Study; Design of Experiment

(2 x 2 Replicated Factorial Design:
8 mature wether lambs)

Lamb No.	Metabolic Body Size (Kg. 3/4)	Silo No.	Maturity	Degree of Chop[1]
20	15.3	3	Sept. (32.1% DM)	Fine
22	12.6	3	Sept. (32.1% DM)	Fine
23	14.8	1	Oct. (51.3% DM)	Fine
25	11.9	2	Oct. (38.8% DM)	Medium
30	12.6	4	Sept. (29.8% DM)	Medium
33	13.4	4	Sept. (29.8% DM)	Medium
34	13.0	1	Oct. (51.3% DM)	Fine
35	11.9	2	Oct. (38.8% DM)	Medium

[1]Fine = 3/8-inch chop.
Medium = 1/2-inch to 3/4-inch chop.

APPENDIX III

RAW DATA

APPENDIX III - TABLE 1a

Effect of Stage of Maturity and Fineness of Chop
on Beef Cattle Performance
January 13, 1967 to July 12, 1967 (180 Days)

Date of Harvest	September Harvest			
Degree of Chop	Fine		Medium	
Method of Feeding	As Ensiled			
Lot Number	14	21	20	22
No. of animals	9	9	9	9
Av. initial weight. lbs.	540	537	536	539
Av. final weight, lbs.	1063	1051	1053	1046
Total gain, lbs.	523	514	517	507
Av. daily gain, lbs.	2.91	2.86	2.87	2.82
Av. Daily Ration, lbs.				
Corn silage fed	33.36	33.00	32.54	33.55
Corn silage consumed 1	33.30	32.70	32.30	33.12
85% dry matter shelled corn	7.35	7.32	7.15	7.21
Protein supplement	0.98	0.99	0.98	0.99
TOTAL, 85% dry matter basis	19.52	19.37	18.30	18.69
Feed consumed per cwt. gain, lbs.				
TOTAL, 85% dry matter basis	678	677	638	662
Daily feed per 100 lbs. body wt., lbs.				
TOTAL, 85% dry matter basis	2.44	2.44	2.30	2.36
Concentrates 2	1.04	1.05	1.02	1.04
Roughage	1.40	1.39	1.28	1.32
Concentrate:Roughage Ratio 3	66.34	66:34	67:33	66:34
Feed cost per cwt. gain 4	$11.34	$11.49	$10.97	$11.36

1 Corn silage consumed - does not include the portion of silage fed which was refused by the steers.
2 Does not contain grain content of corn silage.
3 Does contain grain content of corn silage.
4 Feed prices used: Corn silage - $7.50 per ton on 30% DM basis; Shelled Corn - $1.20 per bushel; MSU-64 Supplement - $5.50 per cwt.

APPENDIX III - TABLE 1b

Effect of Stage of Maturity and Fineness of Chop
on Beef Cattle Performance
January 13, 1967 to July 12, 1967 (180 Days)

Date of Harvest	October Harvest			
Degree of Chop	Fine		Medium	
Method of Feeding	As Ensiled	Reground	As Ensiled	Reground
Lot Number	15	17	23	19
No. of animals	9	9	9	9
Av. initial weight, lbs.	540	537	538	538
Av. final weight, lbs.	1045	1030	1005	1016
Total gain, lbs.	505	493	467	478
Av. daily gain, lbs.	2.81	2.74	2.59	2.66
Av. Daily Ration, lbs.				
Corn silage fed	19.61	19.17	20.35	19.23
Corn silage consumed 1	19.31	19.05	19.51	19.06
85% dry matter shelled corn	7.21	7.02	7.13	6.95
Protein supplement	0.98	0.97	0.99	0.96
TOTAL, 85% DM basis	19.19	18.74	18.84	18.06
Feed consumed per cwt. gain, lbs.				
TOTAL, 85% DM basis	683	695	727	679
Daily feed per 100 lbs. body weight, lbs.				
TOTAL, 85% DM basis	2.42	2.39	2.44	2.32
Concentrates 2	1.03	1.02	1.05	1.01
Roughage	1.39	1.37	1.39	1.31
Concentrate:Roughage Ratio 3	66:34	66:34	66:34	66:34
Feed cost per cwt. gain 4	$11.57	$11.60	$12.40	$11.63

1 Corn silage consumed - does not include the portion of silage fed which was refused by the steers.
2 Does not contain grain content of corn silage.
3 Does contain grain content of corn silage.
4 Feed prices used: Corn silage - $7.50 per ton on 30% DM basis; Shelled corn - $1.20 per bushel; MSU - 64 Supplement - $5.50 per cwt.

APPENDIX III - TABLE 1c

Effect of Stage of Maturity and Fineness of Chop on Beef Cattle Performance
January 13, 1967 to July 12, 1967 (180 Days)

Date of Harvest	November Harvest			
Degree of Chop	Fine		Medium	
Method of Feeding	As Ensiled	Reground	As Ensiled	Reground
Lot Number	16	24	13	18
No. of animals	9	9	9	9
Av. initial weight, lbs.	538	537	538	540
Av. final weight, lbs.	1028	1047	1028	1019
Total gain, lbs.	490	510	490	479
Av. daily gain, lbs.	2.72	2.83	2.72	2.66
Av. Daily Ration, lbs.				
Corn silage fed	17.75	17.06	18.91	17.57
Corn silage consumed 1	17.19	16.92	17.65	17.27
85% dry matter shelled corn	7.15	7.00	7.09	6.59
Protein supplement	0.97	0.95	0.97	0.96
TOTAL, 85% DM basis	19.74	19.17	19.73	18.49
Feed consumed per cwt. gain, lbs.				
TOTAL, 85% DM basis	726	677	725	695
Daily feed per 100 lbs. body weight, lbs.				
TOTAL, 85% DM basis	2.52	2.42	2.52	2.37
Concentrates 2	1.04	1.00	1.03	0.97
Roughage	1.48	1.42	1.49	1.40
Concentrate:Roughage Ratio 3	65:35	65:35	65:35	65:35
Feed cost per cwt. gain 4	$12.13	$11.35	$12.10	$11.67

1 Corn silage consumed - does not include the portion of silage fed which was refused by the steers.
2 Does not contain grain content of corn silage.
3 Does contain grain content of corn silage.
4 Feed prices used: Corn silage - $7.50 per ton on 30% DM basis; Shelled corn - $1.20 per bushel; MSU - 64 Supplement - $5.50 per cwt.

APPENDIX III - TABLE 2a

September vs. October Harvest, Fine vs. Medium Chop, Zero vs. One Per Cent Concentrate Level
(November 17 to July 1, 1968) 1

Date of Harvest	September Harvest				October Harvest			
Degree of Chop	Fine		Medium		Fine		Medium	
Level of Concentrates	0%	1%	0%	1%	0%	1%	0%	1%
Lot No.	2 & 14	10 & 12	8 & 15	1 & 9	7 & 11	3 & 16	4 & 5	6 & 13
Days on Experiment	228	200	228	200	228	200	228	200
No. of Steers	16	16	16	16	16	16	16	16
Av. initial weight. lbs.	478	475	483	477	476	479	477	478
Av. final weight, lbs.	1030	1043	1024	1026	1017	991	1008	998
Av. daily gain, lbs.	2.42	2.85	2.37	2.75	2.37	2.56	2.33	2.61
Av. daily feed, lbs.								
Corn silage (as fed)	44.39	34.02	42.93	33.22	30.55	22.32	34.22	25.80
Shelled corn	---	6.32	---	6.11	---	6.14	---	6.20
Supplement	.99	.98	.99	.99	.99	.96	.99	.97
TOTAL, 85% DM basis	16.28	19.04	15.39	18.37	17.19	19.08	15.99	18.31
Daily Feed/100 lbs. body weight, lbs.								
Concentrate 2	.94	1.58	.90	1.54	1.00	1.62	.94	1.57
Roughage	1.22	.93	1.15	.90	1.31	.98	1.21	.91
TOTAL, 85% DM basis	2.16	2.51	2.05	2.44	2.31	2.60	2.15	2.48
Concentrate:Roughage Ratio 3	6:94	38:62	7:74	39:62	6:94	37:63	6:94	39:61
85% DM Consumed/100 lbs. gain, lbs.	668	668	649	668	725	746	683	703
Feed Cost/100 lbs. gain 4	$11.60	$11.68	$11.28	$11.75	$12.38	$13.01	$11.80	$12.36

See page 148 for footnotes.

APPENDIX III - TABLE 2b

September vs. October Harvest, Fine vs. Medium Chop, Zero vs. One Per Cent Concentrate Level (November 17, 1967 to July 1, 1968)

Date of Harvest	September Harvest				October Harvest			
Degree of Chop	Fine		Medium		Fine		Medium	
Level of Concentrates	0%	1%	0%	1%	0%	1%	0%	1%
Live Selling Price per cwt.	$24.80	$26.20	$24.74	$25.49	$25.39	$25.42	$23.62	$22.86
Carcass Evaluation:								
No. of Animals	8	8	8	8	8	8	8	8
Carcass grade 5	11.50	12.13	10.50	11.25	10.88	11.13	11.25	10.25
Marbling Score 6	14.38	16.38	12.38	13.63	12.50	13.25	14.00	17.00
Fat Thickness, 13th rib, in.	.59	.62	.49	.72	.68	.49	.52	.51
Ribeye area, sq. in.	11.20	10.93	11.31	11.27	11.58	10.94	10.97	10.58
% Kidney, heart and pelvic fat	1.81	2.13	1.75	2.00	1.63	1.75	1.56	1.50
Cutability 7	48.86	49.03	50.57	48.94	49.70	50.39	50.57	49.79
Cold carcass weight, lbs.	591	628	591	611	597	579	554	618
Dressing per cent, %	57.08	60.04	57.95	58.94	59.22	58.78	54.85	53.72
Carcass price per cwt.	$43.44	$43.63	$42.69	$43.25	$42.88	$43.25	$43.06	$42.56

Footnotes for Appendix Tables 4 and 5.

1 Performance data includes all animals in the treatment, whereas carcass data includes a random slaughter of one-half of the animals. The remainder are being fed to heavier slaughter weights.
2 Does not contain grain content of corn silage.
3 Does contain grain content of corn silage.
4 Feed prices used: Corn Silage - $7.50 per ton on 30% DM basis; Shelled Corn - $1.20 per bushel; MSU 64 Supplement - $5.50 per cwt.
5 Carcass grade values: 7 = Standard; 10 = Good; 13 = Choice; 16 = Prime.
6 Marbling values: 11 = Slight; 14 = Small; 17 = Modest 20 = Moderate; 23 = Slightly abundant.
7 Percent boneless, trimmed, retail cuts.

APPENDIX III - TABLE 3

Sheep Parameters

Sheep No.	Silo No.	Dry Matter Intake gm./day	Metabolic Body Weight (Kg. 3/4)	Fecal Dry Matter gm./day	Dry Matter Digestibility Per Cent
20	3	881.8	15.3	317.2	64.03%
22	3	694.1	12.6	261.2	62.37%
23	1	901.1	14.8	262.3	70.89%
25	2	613.8	11.9	201.5	67.17%
30	4	542.1	12.6	187.1	65.49%
33	4	651.8	13.4	183.3	71.88%
34	1	801.9	13.0	274.1	65.82%
35	2	524.9	11.9	143.4	72.68%

APPENDIX III - TABLE 4

Daily Nitrogen Metabolism Data

Sheep No.	Silo No.	Nitrogen Intake gm.	Fecal Nitrogen gm.	Absorbed Nitrogen gm.	Urinary Nitrogen gm.	Excreted Nitrogen gm.	Retained Nitrogen gm.
20	3	10.17	4.82	5.35	2.566	7.386	+2.78
22	3	8.02	4.68	3.34	2.0418	6.7218	+1.30
23	1	10.47	4.59	5.88	2.774	7.364	+3.11
25	2	9.21	3.81	5.40	2.376	6.186	+3.02
30	4	7.24	3.84	3.40	2.872	6.272	+0.53
33	4	8.64	3.67	4.97	2.716	6.386	+2.25
34	1	9.02	5.18	3.84	2.139	7.319	+1.70
35	2	7.92	2.70	5.22	3.317	6.017	+1.90

APPENDIX III - TABLE 5

Rumen Volatile Fatty Acids (μm/ml) at T_0

Sheep No.	Silo No.	Acetic	Propionic	Isobutyric	Butyric	Total
20	3	16.90	12.93	2.41	8.27	40.51
22	3	16.93	17.61	1.05	7.04	42.63
23	1	25.12	13.76	1.78	9.44	50.10
25	2	14.25	10.82	0.97	7.62	33.66
30	4	17.54	12.20	0.93	6.07	36.74
33	4	20.12	14.46	0.99	6.30	41.87
34	1	13.02	10.82	0.81	5.83	30.48
35	2	17.22	11.29	1.55	7.19	37.25

APPENDIX III - TABLE 6

Rumen Volatile Fatty Acids (μm/ml) at T_2

Sheep No.	Silo No.	Acetic	Propionic	Isobutyric	Butyric	Total
20	3	17.82	19.88	0.46	6.04	44.20
22	3	25.05	29.34	1.46	11.92	67.77
23	1	28.11	15.86	1.70	11.51	57.18
25	2	20.91	19.07	1.13	9.71	50.82
30	4	24.74	21.00	1.05	5.53	52.32
33	4	22.98	24.76	0.85	7.96	56.55
34	1	18.89	18.60	1.25	9.39	48.13
35	2	12.87	9.78	0.76	6.18	29.59

APPENDIX III - TABLE 7

Rumen Volatile Fatty Acids (µm/ml) at T_4

Sheep No.	Silo No.	Acetic	Propionic	Isobutyric	Butyric	Total
20	3	20.61	20.20	1.14	8.27	50.22
22	3	21.23	19.75	0.81	7.25	49.04
23	1	30.64	16.51	1.13	12.04	60.32
25	2	21.37	15.22	1.38	10.18	48.15
30	4	21.08	17.18	0.94	6.42	45.62
33	4	18.46	16.41	0.61	5.92	41.40
34	1	21.11	20.75	1.88	6.63	50.37
35	2	13.61	8.82	1.02	7.70	31.15

APPENDIX III - TABLE 8

Rumen Volatile Fatty Acids (µm/ml) at T_6

Sheep No.	Silo No.	Acetic	Propionic	Isobutyric	Butyric	Total
20	3	17.17	17.44	1.72	8.53	44.86
22	3	20.24	20.11	1.32	7.83	49.50
23	1	25.51	13.57	2.10	9.90	51.08
25	2	22.44	13.94	1.78	9.22	47.38
30	4	22.47	18.98	1.41	7.76	50.62
33	4	17.16	15.13	0.69	6.02	39.00
34	1	17.04	19.35	0.89	6.86	44.14
35	2	13.61	8.06	1.02	5.96	28.65

APPENDIX IV

CORRELATION COEFFICIENTS

APPENDIX IV - TABLE 1

Simple Correlation Coefficients - Experiment 4 - Metabolic Study

Variable I	Variable II	r
Silage dry matter	Dry matter intake	0.490
Silage dry matter	% digestible dry matter	0.241
Silage dry matter	Nitrogen intake	0.507
Silage dry matter	Fecal nitrogen	0.348
Silage dry matter	Urinary nitrogen	-0.120
Silage dry matter	Nitrogen retention	0.374
Silage dry matter	Silage water soluble nitrogen	-0.600
Silage dry matter	Silage NPN	-0.943**
Silage dry matter	Silage NH_3 N	-0.040
Silage dry matter	Silage pH	0.567
Silage dry matter	Silage lactic acid	-0.913**
Dry matter intake	% digestible dry matter	-0.22
Dry matter intake	Nitrogen intake	0.863**
Dry matter intake	Fecal nitrogen	0.811**
Dry matter intake	Urinary nitrogen	-0.40
Dry matter intake	Nitrogen retention	0.531
Dry matter intake	Silage water soluble nitrogen	-0.842**
Dry matter intake	Silage NPN	-0.657*
Dry matter intake	Silage NH_3 N	-0.738*
Dry matter intake	Silage pH	-0.049
Dry matter intake	Silage lactic acid	-0.325
% digestible dry matter	Nitrogen intake	0.076*
% digestible dry matter	Fecal nitrogen	-0.656
% digestible dry matter	Urinary nitrogen	0.727*
% digestible dry matter	Nitrogen retention	0.345
% digestible dry matter	Silage water soluble nitrogen	0.395
% digestible dry matter	Silage NPN	-0.104
% digestible dry matter	Silage NH_3 N	0.564
% digestible dry matter	Silage pH	0.263
% digestible dry matter	Silage lactic acid	-0.243
Nitrogen intake	Fecal Nitrogen	0.503
Nitrogen intake	Urinary nitrogen	-0.181

Simple Correlation Coefficients - Experiment 4 - Metabolic Study

Variable I	Variable II	r
Nitrogen intake	Nitrogen retention	0.875**
Nitrogen intake	Silage water soluble nitrogen	-0.613
Nitrogen intake	Silage NPN	-0.537
Nitrogen intake	Silage NH_3 N	-0.326
Nitrogen intake	Silage pH	0.247
Nitrogen intake	Silage lactic acid	-0.466
Fecal nitrogen	Urinary nitrogen	-0.779*
Fecal nitrogen	Nitrogen retention	0.091
Fecal nitrogen	Silage water soluble nitrogen	-0.802
Fecal nitrogen	Silage NPN	-0.567
Fecal nitrogen	Silage NH_3 N	-0.844**
Fecal nitrogen	Silage pH	-0.233
Fecal nitrogen	Silage lactic acid	-0.147
Urinary nitrogen	Nitrogen retention	0.009
Urinary nitrogen	Silage water soluble nitrogen	0.524
Urinary nitrogen	Silage NPN	0.237
Urinary nitrogen	Silage NH_3 N	0.525
Urinary nitrogen	Silage pH	0.097
Urinary nitrogen	Silage lactic acid	0.061
Nitrogen retention	Silage water soluble nitrogen	-0.286
Nitrogen retention	Silage NPN	-0.271
Nitrogen retention	Silage NH_3 N	0.107
Nitrogen retention	Silage pH	0.470
Nitrogen retention	Silage lactic acid	-0.476
Silage water soluble nitrogen	Silage NPN	0.705*
Silage water soluble nitrogen	Silage NH_3 N	0.688*
Silage water soluble nitrogen	Silage pH	-0.213
Silage water soluble nitrogen	Silage lactic acid	0.533
Silage NPN	Silage NH_3 N	0.340
Silage NPN	Silage pH	0.277
Silage NPN	Silage lactic acid	0.742*

APPENDIX IV - TABLE 1 (Cont.)

Simple Correlation Coefficients - Experiment 4 - Metabolic Study

Variable I	Variable II	r
Silage NH_3 N	Silage pH	0.559
Silage NH_3 N	Silage lactic acid	0.205
Silage pH	Silage lactic acid	-0.849**

	Critical values[1]
* ($P < .05$)	.650
** ($P < .01$)	.798

1 Snedecor, 1946

APPENDIX V

VERIFICATION OF DRY MATTER DETERMINATIONS

VERIFICATION OF DRY MATTER DETERMINATIONS

The accuracy of dry matter determination of feedstuffs containing volatile acids and bases has been questioned by many authors, but no accurate method has been devised which does not involve use of exhaustive extraction and distillation techniques.

The two methods most commonly used in work with silages and similar fermentation products are oven-drying and distillation. Distillation procedures involve the use of organic solvents which are nonmiscible in water and have a boiling point higher than water (commonly toluene is used for this purpose, Bidwell and Sterling, 1923).

Oven-drying at 65° C, as described by Barnett (1954), not only removes most of the water but also some organic matter, distinctly noticeable because of the pleasant aroma associated with drying silage (Fenner and Barnes, 1965). Forbes (1943) used drying in a vacuum oven for 22 hours at 50° C and employed a closed system, drawing heated, dry, and CO_2-free air through the sample into a red-hot furnace, where a platinum catalyst oxidized the organic matter into CO_2 and water. The water and CO_2 were trapped quantitatively in concentrated sulfuric acid and flaked sodium hydroxide, respectively. The increase in weight of sodium hydroxide represented the CO_2 from the oxidized organic matter removed from the sample by the drying air. The amount of removed organic matter was calculated, assuming that it represents acetic acid only.

McDonald and Dewar (1960) used a similar approach with a regular oven at 100° C. Hot, dry and CO_2-free air was pumped through the sample and through a Liebig condenser. The precipitate was collected in a salt and ice-cooled vessel. Before entering the atmosphere, the air was forced to pass through traps of silica gel to remove the water, then through soda-lime for the absorption of volatile acids and, finally, through a standard acid solution for removal of volatile bases. This assured a complete recovery of organic matter. Ammonia, ethanol, acetic, propionic, butyric, and lactic acids were determined quantitatively in the condensate and added to the oven-dried dry matter.

Fenner and Barnes (1965) reported that the use of organic solvents for the determinations of dry matter was first reported in 1904. Perkins (1943) reported that 95% of the acetic acid of the sample was found in the water, after having been removed from the dry matter by the toluene method.

Fenner and Barnes (1965) concluded that, in general, with good corn silages, the toluene-extracted water required only the titration values of the steam distillate for volatile bases and acids to make the dry matter correct. If this is not done, they concluded, the error could reach a 10% underestimation of dry matter.

To verify the procedure used in this study, corn silage dry matter determinations were conducted in the following ways:

1. Toluene (AOAC method with 2-1/2 hours of distillation).
2. Oven dry matter - 105° C.
    a. 24-hour drying.
    b. 48-hour drying.

3. Oven dry matter - 55° C

a. 24-hour drying

b. 48-hour drying

The following results were obtained:

Sample No.	Per Cent Dry Matter as Determined By:					% of Error 1
	Toluene %	105° C Oven		50° C Oven		
		24 hrs. %	48 hrs. %	24 hrs. %	48 hrs. %	
1	25.5	25.0	25.0	24.1	23.7	7.1
2	24.0	24.3	23.8	23.1	23.1	7.6
3	25.5	22.5	21.6	21.7	21.7	14.9
4	51.1	42.0	41.2	40.0	40.0	21.7
5	50.3	40.8	39.6	40.9	40.9	18.7
6	55.8	43.3	43.1	42.3	42.3	24.2
				Mean error		15.7

1 % error is the error between the mean of the oven determination and the toluene determination.

Shown in this table are the results comparing the toluene distillation with various oven drying methods. In this work the error comparing the two methods ranged from 7.1% to 24.2% with a mean error of 15.7%. The oven dry matter values certainly appeared more valid and it was concluded that not all of the water had been removed during the distillation with the toluene. To further verify methods and procedures, a second trial was conducted utilizing

1. Toluene (2-1/2 hour distillation) using a ground sample.

2. Oven drying (55° C) using a ground sample.

The following results were obtained:

Sample No.	Dry Matter Determination as Analyzed on a Ground Silage Sample by:		% of Error
	Toluene %	105° C Oven %	
1	33.73	30.25	10.37
2	33.34	33.13	0.63
3	33.60	34.31	2.13
		Average error	4.37

These results compare the two methods after the silage samples were chopped in a Waring Blender for one minute. This reduced the partical size and the results compared much better than before with only 4.37% error. The pH values of the toluene distillate certainly provided evidence that the volatile acids were not remaining in the sample as dry matter.

After reviewing the literature and the results of the above trials, it was concluded that oven drying at 55° C for 24 hours gave satisfactory results. It was further concluded that the accuracy would not be improved without going to extreme distillation and recovery methods for dry matter determinations, as described by Forbes (1943) and McDonald and Dewar (1960), which was not within the financial resources of this project.