HAY AND SILAGE STUDIES WITH DAIRY CATTLE

Thesis for the Degree of Ph. D.
MICHIGAN STATE UNIVERSITY
LEONARD D. BROWN
1961

This is to certify that the

thesis entitled

Hay and Silage Studies
with Dairy Cattle

presented by

Leonard D. Brown

has been accepted towards fulfillment
of the requirements for

Ph. D. degree in Agriculture

C. A. Lassiter
Major professor

Date November 21, 1961

O-169

HAY AND SILAGE STUDIES WITH DAIRY CATTLE

By

Leonard D. Brown

AN ABSTRACT OF A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Dairy

1961

ABSTRACT

HAY AND SILAGE STUDIES WITH DAIRY CATTLE

by Leonard D. Brown

During a three-year period, a series of experiments were conducted to determine the relative feeding value of alfalfa hay, alfalfa silage, corn silage, and combinations of each silage with hay for lactating dairy cows. Preliminary studies were conducted to determine the affect of adding organic solvents to direct-cut alfalfa stored in glass jars and conventional silos.

In Experiment I, alfalfa silage was fed ad libitum and hay feeding controlled to 0.0, 25.0, 75.0, and 100 per cent of the ration dry matter. Combined data from two trials showed significantly ($P < 0.05$) greater dry matter consumption per 100 pounds body weight of groups fed all hay, 75 per cent hay, and 50 per cent hay, than of groups fed all silage rations. Similarly, the all hay group and 75 per cent hay group consumed significantly more dry matter per 100 pounds body weight than the 25 per cent hay group. The milk production followed a trend similar to dry matter consumption; however, the differences among groups were not significant. The average pounds of milk per day for the 90-day trial were 30.4, 30.1, 31.2, 31.4, and 31.2 for the all silage, 25 per

cent hay, 50 per cent hay, 75 per cent hay, and all hay groups, respectively. Differences among ration groups in persistency of milk production or in body weight gain were not significant. There was a general trend for body weight gain to increase as the level of hay in the ration increased. The average 90-day change in body weight for both trials was -69.1, -49.6, -4.6, +33.8, and +13.2 for the all silage, 25 per cent hay, 50 per cent hay, 75 per cent hay, and all hay groups, respectively. When dry matter consumption, four per cent FCM production, and body weight change were all considered, the dry matter from silage appeared to be more efficiently utilized than dry matter from hay.

In a second experiment, cows consumed significantly ($P < 0.01$) more dry matter from alfalfa hay than from alfalfa silage. Grain feeding significantly ($P < 0.01$) decreased dry matter consumption from either hay or silage but significantly ($P < 0.01$) increased total dry matter consumption (roughage dry matter plus grain dry matter). In this study, cows consuming silage produced significantly ($P < 0.01$) more milk than cows consuming hay. The average daily milk production of cows fed hay was 29.2 pounds as compared to 34.8 pounds for cows fed silage. In like manner the average daily milk production of cows fed only roughage (hay or silage) was 27.8 pounds compared to 35.2 pounds for cows fed roughage plus

grain. When the data from both roughage groups were combined, it was observed that each pound of grain dry matter fed replaced approximately 0.56 pounds of roughage dry matter and produced an additional 0.82 pounds of four per cent FCM and 0.06 pounds of body weight gain per day.

In Experiment III, two separate trials were conducted to determine the relative feeding value of hay and corn silage fed separately and in combination to lactating dairy cows. Similar results in dry matter consumption were observed in these trials as that observed in Experiment I. In general, dry matter consumption increased as the level of hay in the ration increased. Body weight gain followed a trend similar to dry matter consumption. The differences among groups in milk production were not significant. The average daily milk production was 36.1, 38.2, 34.7, 36.0, and 34.8 pounds for groups receiving ad libitum corn silage, corn silage plus 10 pounds of hay, corn silage plus 20 pounds of hay, corn silage plus 30 pounds of hay, and ad libitum hay, respectively. Similarly, the differences among ration groups in persistency of milk production were not statistically significant. Based on this work, it appears that a pound of dry matter from corn silage is more efficiently utilized for milk production than a pound of dry matter from hay.

Leonard D. Brown

Preliminary observations in the laboratory indicated beneficial effects from adding small quantities of 95 per cent ethanol to direct-cut alfalfa stored in glass jars. Therefore, a larger scale experiment was designed to determine any changes in feeding value of forage preserved with two levels of denatured ethanol as compared to the same forage preserved with sodium metabisulfite. In a 30-day growth trial, heifers fed the ethanol preserved forage gained approximately 0.5 pounds more per day than heifers fed metabisulfite preserved forage. The average daily dry matter consumption of heifers was 14.0, 13.2, and 13.7 pounds for the metabisulfite forage, 1.0 per cent ethanol forage, and 3.0 per cent ethanol forage groups, respectively. The average gain per 100 pounds of dry matter consumed was 7.28, 10.98, and 12.26 pounds, respectively, in the same order.

Additional studies were conducted to determine the effect of adding formalin, ethyl acetate, butyl alcohol, and acetone to direct-cut alfalfa stored in glass jars. Based on human preference tests, acetone and formalin appeared promising. Additional work is currently in progress to further elucidate the mode of action of formalin, ethanol, acetone, and other organic solvents in forage preservation.

HAY AND SILAGE STUDIES WITH DAIRY CATTLE

By

Leonard D. Brown

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Dairy

1961

ACKNOWLEDGEMENTS

The author expresses sincere appreciation to Dr. C. A. Lassiter, Head of the Department of Dairy, and to Dr. C. F. Huffman, Professor Emeritus of the Department of Dairy, for their many hours of counsel and timely suggestions throughout the course of this study and for their critical reading of the manuscript; to Dr. R. S. Emery, Associate Professor of the Department of Dairy, Dr. J. W. Thomas, Professor of the Department of Dairy, and Dr. Don Hillman, Assistant Professor of the Department of Dairy, for their critical reading and assistance in preparing the manuscript.

The author also expresses appreciation to Dr. E. J. Benne, Professor of the Department of Biochemistry, and to Mrs. Dorothy Carpenter, Dairy Laboratory Technician, who performed the chemical analyses of the feed samples, and to Mr. Dennis Armstrong, Mr. Ralph Reid, and Mr. Warren Hutchinson for their assistance in feeding and caring for the experimental animals.

The author is especially grateful to his wife Helen and to their daughters, Marcia and Melayna, for their loving faith and constant encouragement throughout the course of this study.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued

INTRODUCTION

Preservation and storage of excellent quality forage is an ever pressing problem with dairymen throughout the world. It is generally recognized that good forage is the most economical source of nutrients for ruminants, and its role in their daily ration usually means the difference between a profitable or unprofitable dairy operation. Since this is true, it behooves the dairyman to have not only a good pasture program in the summer, but to preserve and store a large portion of this highly nutritious feed for winter feeding. The two principle methods of forage preservation are (1) hay and (2) silage. It is generally recognized that hay is the most important harvested roughage in the United States in that over 100 million tons are made each year with an estimated value of nearly two billion dollars. However, recent advances in forage harvesting and feed handling equipment have brought about widespread interest in the use of more silage in dairy cattle rations. In fact, several dairymen in Michigan are changing to a complete stored feeding system with silage playing the predominant role in their forage program. Therefore, additional information concerning the relative feeding value of silage and hay is desirable.

The data reported herein are results of studies comparing the relative feeding value of alfalfa hay and alfalfa

silage (with and without supplemental grain) for lactating dairy cows. Additional data are reported, concerning the relative feeding value of alfalfa hay and corn silage. Preliminary observations are reported on methods of improving the feeding value of direct-cut alfalfa forage stored in conventional silos.

REVIEW OF LITERATURE

Factors affecting the appetite of dairy cattle as well as the relative feeding value of hay and silage for dairy cattle have recently been comprehensively reviewed by Hillman (32). In this review an attempt was made to add current information to Hillman's review and, more precisely, to review related material in an attempt to more clearly elucidate the apparent differences in feeding value of hay and silage. Three general areas are covered: (1) hay vs. silage as feeds for mature dairy cattle, (2) hay vs. silage as feeds for growing dairy cattle, and (3) silage preservation as influenced by microbiological and chemical changes and the relationship of these changes to the feeding value of the silage.

Hay vs. Silage: Feeding Value for Mature Dairy Cattle

Since roughages are generally the cheapest source of nutrients, it is essential to obtain maximum roughage intake. In order to accomplish this the appetite of the animal must be considered. Appetite as defined by Huffman (36) is the total amount of dry matter consumed when the animal is fed *ad libitum*. It was also pointed out in this review that food consumption is affected by factors inherent in the animal as well as factors inherent in the feed. Factors given consideration in the feed are palatability, amount of feed offered,

bulk and balance of the ration. Since it is rather difficult to change the factors inherent in the animal, considerable research has been directed toward changes in the palatability of roughages stored by different methods. In order to be able to properly evaluate the success of storing roughages, it is necessary to compare the acceptability of the stored product to the acceptability of the fresh forage as well as comparing the different methods of preservation. In general, milking cows receiving no supplemental feed will consume approximately 30.0 pounds of pasture dry matter per 1000 pounds body weight per day when an abundance of fresh succulent pasture is available (Huffman, 37). This amount of dry matter from pasture supplies sufficient quantities of total digestible nutrients (TDN) to supply the cows maintenance requirements plus 30-40 pounds of four per cent fat corrected milk (FCM) per day. However, since considerable nutrient loss is experienced in storage as well as a decrease in digestibility, it becomes necessary to obtain a higher dry matter intake from stored forage (hay or silage) to supply the same TDN.

Graves et al. (27), using hay and silage cut from the same field at the same stage of maturity, reported that cows consumed approximately 6.0 pounds more dry matter per day from grass in the form of hay than in the form of silage. No supplemental grain was fed to either group. In a second

experiment using a similar experimental design, it was observed that lactating dairy cows consumed approximately eight pounds more dry matter per day from grass hay than from grass silage. The hay had an average dry matter content of 83.3 per cent as compared to the silage with an average dry matter content of 25.2 per cent. The difference in dry matter consumption by these two groups was reflected in a change in body weight. The hay group lost approximately 0.8 pounds per day per cow whereas the silage group lost approximately 1.5 pounds per day. Even though a considerable difference was noted in dry matter consumption and loss in body weight, only slight differences were observed in persistency of milk production. This indicated to the authors that the silage (pound for pound of dry matter) had a greater feeding value for milk production than the grass hay. It should be pointed out, however, that the duration of these trials was entirely too short to make any real comparison of the prolonged effect on milk production. The hay trial lasted only 20 days whereas the silage trial lasted 40 days.

Horwood and Wells (35), using a double-reversal experimental design, compared alfalfa-molasses silage with alfalfa hay as the sole roughage for dairy cattle. When the intake of these roughages was controlled, the silage group produced slightly more milk whereas the hay group

gained more in body weight. Neither of these differences were found to be significant. Similarly, Graves et al. (26) reported that cows on an all grass hay ration consumed approximately 10 pounds more dry matter per day for the entire lactation period than did cows on an all grass silage ration. These workers also reported that the average amount of dry matter consumed per pound of milk produced was somewhat greater for the grass hay group than for the silage group. This cannot be interpreted to mean that the dry matter in grass silage was more efficiently used for milk production than that in grass hay since both groups consumed more than enough dry matter to meet their requirements and, of course, the excess consumption was greater for the hay group.

Hodgson and Knott (34) conducted two experiments comparing the nutritive value for milk production of a ration made up exclusively of clover-mixed hay plus grass silage with a ration consisting solely of alfalfa hay. The first experiment was continued for 168 days whereas the second experiment was terminated after 140 days. In the first experiment, the cows receiving mixed clover hay plus grass silage consumed an average of only 26.1 pounds of dry matter per day as compared to 33.2 pounds for the cows receiving all hay. In the second experiment, the cows receiving mixed hay plus silage consumed 26.3 pounds of dry matter per day compared to 33.4 pounds for the group receiving alfalfa

hay. In both experiments, the groups receiving hay plus silage consumed approximately 57.7 per cent of their daily dry matter from hay. The differences in dry matter intake between the two groups were reflected in changes in body weight and milk production with the all-hay group being somewhat superior in both respects.

Ely et al. (18) compared the feeding value of second-cut alfalfa stored as wilted silage, barn-cured hay, and dehydrated hay. All forages were harvested at the same time with a field chopper using a four-inch cut for the barn-cured, 1/4-inch cut for the dehydrated, and 3/8-inch cut for the silage. When fed according to appetite, only slight differences were observed in dry matter consumption between the groups receiving silage vs. barn-cured hay. However, slightly more dry matter was consumed by the cows receiving the dehydrated hay. Little difference was observed in persistency of milk production between the two hay groups. However, both were somewhat higher in this respect than the silage group. This difference can probably be explained on the basis of dry matter intake.

Blosser et al. (6) reported that cows receiving either alfalfa-grass silage or pea vine silage fed according to appetite showed a marked craving for some dry roughage in their ration. When some medium quality alfalfa hay was added to the ration, cows consumed approximately 1.0 pound more dry

matter from their roughage per day and produced approximately 1.1 pounds more milk. Grain was fed to both groups at the rate of 1.0 pound of grain for each 3.0 pounds of four per cent FCM. It was concluded that at least some hay should be fed to dairy cows in order to maintain maximum production.

Trimberger (86) made comparisons of barn-dried hay, field-cured hay, and hay-crop silage when harvested at the same and different stages of maturity. When six pounds of second-cut mixed hay were added to all rations, the dry matter intake for the roughages harvested at the same stage of maturity were 24.4, 24.5, and 23.1 pounds, respectively, for barn-dried hay, field-cured hay, and hay-crop silage. Grain was fed at the same rate for all cows. It was also found that cows consumed more dry matter from early-cut silage (boot stage) than from hays cut at later stages of maturity.

Keys and Smith (51) compared the feeding value of chopped, baled, and loose hay and wilted grass silage for milk production. In general, the consumption differences among the hay groups were slight. However, the silage group consumed approximately five pounds less roughage TDN per day than did the group receiving loose hay. The silage group was fed considerably more TDN in the form of grain, however, and thus produced significantly more milk. Body weight gains differed only slightly among any of the four groups.

Huffman et al. (38) reported results comparing the relative feeding value of pea and oat silage. It was observed that cows receiving only silage consumed considerably less dry matter and 25-30 per cent less TDN than when some hay was included in the ration. Similar results were obtained by Huffman et al. (44) concerning the grain equivalent value of pre-bud alfalfa hay, alfalfa-rye-grass silage, and mature alfalfa hay in which average daily FCM production of 34.2, 29.0, and 32.5 pounds, respectively, were obtained. The dry matter intakes were 30.6, 27.5, and 24.7 pounds per day, respectively. Grain feeding was increased 6.0 pounds per day when the cows were changed from the immature rations to the mature hay ration. The TDN intakes of cows on the pre-bud hay, silage, and mature hay rations were 18.7, 15.3, and 19.4 pounds, respectively, which might explain in part the decreased milk production of cows on the silage ration. However, more FCM was produced by cows on the pre-bud alfalfa hay ration with 0.7 pounds less TDN than cows on the mature alfalfa hay ration. In a later study, Huffman et al. (39) reported that Ladino silage was more appetizing to dairy cows than was corn silage but less appetizing than grass hay. The cows only consumed 14.8, 14.4, and 11.4 pounds of dry matter from silage when it replaced 16.2, 17.7, and 17.8 pounds, respectively, of dry matter in hay. However, slightly more dry matter was consumed from the Ladino clover

silage than from corn silage. It was also concluded from this experiment that Ladino clover silage supplies approximately as much grain equivalent value in terms of milk production as corn silage.

In a study utilizing a double-reversal design, Cobble and Wildes (9) found only slight differences in dry matter intake from grass-legume silage fed at 2.0 pounds of hay-equivalent per 100 pounds body weight as compared to an equivalent amount of hay-silage combination. However, in a second study using the same procedure, the cows receiving the hay-silage combination consumed approximately 3.0 pounds more dry matter per day and gained considerably more in body weight than those fed grass-legume silage. Similar results were reported by Pratt and Conrad (72) in which either hay or silage made up from 0.0 to 75.0 per cent of the total dry matter intake of dairy cows. Based on three-years results, these workers found that in general, the dry matter consumption and four per cent FCM increased slightly as the proportions of hay increased in the ration. However, when milk production was adjusted for differences in dry matter intake, silage dry matter was utilized somewhat more efficiently than that from hay. These results are somewhat complicated by the feeding of sufficient grain to supply approximately 25 per cent of the total dry matter.

Nicholson and Parent (67), using lactating Ayrshire cows, compared rations in which the roughage portion was

grass silage alone, or grass silage plus hay at the rate of 1/3, 2/3, and 1 pound hay daily per 100 pounds body weight. The grass silage was fed according to appetite in all cases and grain was fed at the rate of one pound grain for every four pounds of four per cent FCM. No significant differences existed among groups in terms of FCM, butterfat percentage, or changes in body weight. However, there was a progressive increase in dry matter consumption as the level of hay feeding increased. It was also observed that significantly more TDN was required per 100 pounds of four per cent FCM for the group receiving 1.0 pounds of hay per 100 pounds body weight daily than for the all silage group.

Dijkstra (14) observed that cows receiving grass silage (23.8 per cent dry matter) lost body weight and produced somewhat less milk than similar cows fed barn-dried hay or hay plus silage. In the first experimental period, the differences among groups in milk production were very slight. However, in the second period, a very distinct difference was observed which appeared to be associated with a poorer quality silage.

Gordon et al. (21), using first cutting alfalfa, observed dry matter intakes per 100 pounds of body weight of 2.4, 2.2, and 1.8 from barn-dried hay, wilted silage, and direct-cut silage, respectively. The differences among group means were highly significant ($P < 0.01$). The average

milk yield followed similar trends as dry matter intake ($P < 0.05$). However, when expressed as dry matter intake per 100 pounds of FCM, the mean values were 90.5, 85.4, and 72.6 pounds for barn-dried hay, wilted silage, and direct-cut silage groups, respectively. In a second study using second cutting alfalfa, these authors observed a slightly greater dry matter intake from wilted silage than from comparable hay.

Similarly, Shepherd et al. (77) reported comparisons of wilted silage (34.4 per cent dry matter) and half-dry silage (54.3 per cent dry matter) stored in gas-tight silos. The cows receiving the half-dry silage consumed approximately 2.3 pounds more dry matter, were more persistent in milk production, and increased more in body weight than the cows receiving wilted silage. In a second trial, these authors reported no differences in dry matter consumption, milk production, or change in body weight of cows receiving wilted silage (approx. 36 per cent dry matter) stored in a conventional silo as compared to silage stored in a gas-tight silo. In a later report, Shepherd et al. (78) observed that wilted alfalfa silage and dehydrated alfalfa hay were more palatable than comparable field-cured hay or barn-dried hay. It was also observed that when the four experimental roughages were fed on an equalized dry matter basis, the differences among groups in four per cent FCM were not statistically

significant. Changes in body weight were similar among groups. In agreement with these results, Voelker and Bartle (88) observed slightly greater dry matter intake and gain in body weight of cows fed alfalfa haylage (40-52 per cent moisture) than from artificially dried hay. The average four per cent FCM production was similar among groups averaging 37.7 and 37.3 pounds per cow per day for the haylage and hay groups, respectively.

Conversely, Hill et al. (31) compared the performance of milking cows fed either legume-grass silage or hay harvested simultaneously and found that the silage cows consumed slightly more dry matter, produced more milk, and gained more in body weight than cows fed hay. The average daily dry matter intakes and four per cent FCM produced were 30.5, 23.1, and 29.7, 20.4 pounds per cow for the direct-cut silage and hay groups, respectively. Similar results were reported by Trimberger et al. (87), where it was observed that lactating dairy cows consumed equal quantities of dry matter from silage as from hay if both were harvested at the same stage of maturity. However, the cows receiving early-cut silage produced significantly ($P < 0.01$) more four per cent FCM than comparable cows consuming early barn-dried hay, field-cured hay, or late-cut silage. The differences among groups in body weight gain were not significant. In this study each cow received an average of 11.2 pounds of

grain per day. The average dry matter digestibility coefficients were 70.5, 58.5, 57.6, and 52.2 per cent, respectively, for the early-cut silage, barn-dried hay, late-cut silage, and field-cured hay. In a later study, Slack et al. (80) utilized a change over design covering two consecutive years and observed no significant differences in milk production of cows fed silage, barn-dried hay, or a combination of silage plus barn-dried hay. However, all groups produced significantly more milk than cows fed field-cured hay harvested at a more mature stage of growth. In contrast to the previous study, cows consumed significantly more dry matter from the barn-dried hay than from silage. Two levels of grain feeding failed to significantly affect dry matter consumption of the different forages. The grain feeding levels employed were 1.0 pound of grain to 4.0 pounds of milk and 1.0 pound of grain to 6.0 pounds of milk. Cows receiving hay tended to maintain body weight somewhat better than cows receiving silage. In a second study covering a three-year period, a continuous type trial was employed covering twenty weeks in a three by two factorial design (two levels of grain and three experimental roughages). Grain feeding levels calculated as previously mentioned were one to four and one to eight for cows receiving either early-cut silage (24.3 per cent dry matter), early-cut barn-dried hay or late-cut field-cured hay. Cows receiving the low level of grain consumed

significantly ($P < 0.01$) more roughage dry matter than cows fed the high level of grain. It was also observed in this study that significantly ($P < 0.01$) more dry matter was consumed from the early-cut hay than from silage or late-cut hay. However, the cows receiving early silage as the only source of roughage maintained milk production better than cows on either hay. When calculated on a four per cent FCM basis, the silage cows produced significantly ($P < 0.01$) more milk and gained significantly ($P < 0.01$) more body weight than either of the hay groups.

Ramsey et al. (74) found no difference in dry matter consumption or digestibility of oat forage stored as either silage or hay. Similarly Breirem et al. (7) summarized 15 years experimental data and reported that cows fed rations containing silage or artificially dried grass produced more milk than similar cows fed hay when each was fed as the sole source of roughage. These workers also observed that silage fed alone produced equal results to hay plus silage in respect to milk yield and general condition of the cow.

Hillman et al. (33) compared the performance of lactating dairy cows fed either all alfalfa hay or alfalfa silage rations harvested from the same field at the same stage of maturity (late-bud). The cows receiving the all-hay ration consumed approximately 7.3 pounds more dry matter per day and gained significantly more in body weight than the

cows receiving the all-silage ration. However, no significant differences were observed in actual milk production. A second trial was conducted to determine whether moisture or pH were the principle factors affecting the reduced dry matter intake of cows on all-silage rations. Four rations were fed: (1) alfalfa hay, (2) alfalfa hay that had been soaked in water to increase the moisture content equivalent to silage, (3) alfalfa silage, and (4) NaOH silage (regular silage treated with sufficient quantities of sodium hydroxide to adjust the pH equal to that of the hay). The average daily dry matter intakes from the four rations were 35.5, 35.8, 23.7, and 24.7 pounds, respectively. In like manner, the changes in body weight were +10.7, +15.0, -36.9, and -22.6 pounds per cow during a ten-day period. The dry matter intake and gain in body weight on either hay were significantly greater than on either silage. In a later study, Hillman (32) fed silage ad libitum and controlled the hay feeding to 0.0, 25.0, 50.0, 75.0, and 100.0 per cent of the ration dry matter. The average daily dry matter intakes were 26.2, 28.6, 32.8, 35.1, and 41.0 pounds, respectively. Dry matter intakes were significantly greater ($P < 0.01$) for the cows fed all-hay or 75 per cent hay than for cows fed all-silage or 25 per cent hay plus silage. Milk production and changes in body weight followed a pattern similar to that of dry matter intake.

In palatability trials, Shepherd et al. (79) reported no significant differences in dry matter intake of cows fed either wilted alfalfa silage or alfalfa hay. When control feeding was employed only slight differences in milk production were observed among groups. Both forages were harvested from the same field at the same stage of maturity. Similarly, Wittwer et al. (94) observed no significant differences among cow groups fed direct-cut silage, wilted silage (25-30 per cent dry matter), and unwilted silage to which was added 200 pounds dry hay per ton of fresh forage with respect to dry matter intake, body weight change, or four per cent FCM production.

Considerably less data are available comparing the feeding value of corn silage with hay than data comparing grass silage with hay. A summary of several years work showing the average chemical composition, coefficients of digestibility, and TDN content of corn silages has recently been published by Huffman and Duncan (42). The average TDN content was approximately 68.6 per cent which is some 13.0 percentage points higher than excellent quality hay.

Woll and Voorhies (96) found that cows consumed approximately two pounds less dry matter and produced slightly less milk when fed alfalfa hay plus milo silage ad libitum than when fed alfalfa hay alone. However, when Indian corn silage was substituted for the milo silage, a slight increase

in dry matter consumption occurred accompanied by an increased milk flow.

Only minor differences in dry matter consumption or efficiency of utilization of corn silage as compared to grass silage (with three per cent added molasses) were observed by Camburn et al. (8). Similarly, Lassiter et al. (56) observed that oat silage (harvested in the early-dough stage) supported milk production at slightly higher levels than corn silage when both were fed at levels of 63.0 per cent of the total roughage intake. However, when fed at higher levels (77.0 per cent of the total roughage intake) significantly more milk was produced by cows receiving corn silage. Body weight gains followed a pattern similar to milk production.

Huffman and Duncan (40) reported that corn silage contained unidentified factor(s) needed for milk production. In this study all cows were fed an all-hay ration until they showed a marked drop in milk production. The cows were then changed from hay to corn silage on an equalized TDN basis. In general, the cows decreased slightly in body weight but increased considerably in milk production amounting to approximately five pounds per cow per day. Similarly, Dunn et al. (17) observed that on an equalized TDN basis, corn silage supported milk production at a higher level than red clover hay. Indication was obtained that the factors

associated with the increased milk production were related to the grain portion of the corn silage since a grainless corn silage appeared to have about the same "milk-producing power" as hay. The TDN content of the regular corn silage and grainless corn silage was 73.4 and 58.9 per cent, respectively. However, in a later study, Huffman and Duncan (41) observed no significant differences in milk production of cows fed either immature corn silage or well-matured corn silage. These authors concluded that the grain equivalent was in the stalk of the immature corn silage just as it was in young grass.

White and Johnson (91), however, observed no beneficial effects from adding succulent feeds in the form of corn silage or soaked beet pulp over that of mixed hay and grain alone for lactating dairy cows. When water was offered only once daily, the hay group consumed approximately 2.5 pounds more dry matter than the silage group. In general, hay consumption was slightly decreased when animals were watered only once per day as compared to free choice.

Waugh et al. (90) compared corn silage as the sole roughage for lactating dairy cows with similar rations containing 1.0, 0.5, and 0.25 pounds of hay per 100 pounds body weight. Limited quantities of grain were fed to all groups. No significant differences in milk production were observed among groups. However, the total dry matter consumption

significantly ($P < 0.01$) increased as the level of hay in the ration increased. The mean total dry matter intakes were 25.7, 25.1, 22.8, and 21.6 pounds per day for cows receiving the 1.0, 0.5, 0.25, and 0.0 pounds of hay per 100 pounds body weight, respectively. No significant differences in body weight gains were observed. In general, the milk production was lowest on the all-corn silage ration and increased up to the 0.5 pound hay group and then declined slightly in the all-hay group.

Hay vs. Silage: Feeding Value for Growing Dairy Cattle

Sykes *et al.* (83) compared the relative feeding value of alfalfa hay and alfalfa silage for growing dairy heifers. The heifers which were fed alfalfa hay as the only roughage grew at a normal rate as compared to accepted standards. However, when silage was the sole source of roughage, the growth rate was markedly reduced; and at two years of age, the difference in body weight was 91 pounds for Jerseys and 240 pounds for Holsteins as compared to hay-fed animals. When small quantities of hay were fed in addition to the silage, the growth rate was improved somewhat, but still remained below that of the heifers receiving the all-hay ration. These results were confirmed by Thomas *et al.* (84) when it was demonstrated that dairy heifers can be reared to calving

time on limited quantities of whole milk and grain with unlimited quantities of good alfalfa hay. However, when a mixture of wilted alfalfa silage and corn silage was substituted for the hay, a decided drop occurred in both feed consumption and gain in body weight with the final weight of heifers being only 76 per cent of normal. When hay (one pound per 100 pounds body weight) or grain (two pounds per day) was added to a wilted alfalfa silage ration, heifers were only slightly smaller at two years of age than similar heifers reared on alfalfa hay. In general, heifers consumed less roughage dry matter from silage than from hay. In a later report, Thomas et al. (85) reported that the subsequent milk and fat production during the first lactation of the smaller heifers reared on grass silage was somewhat less than heifers reared on hay or hay plus silage.

Bender and Tucker (5) compared the growth rates of a group of dairy heifers receiving only timothy grass silage with a second group which received the same silage plus hay. The average daily gain in body weight by the heifers on timothy silage was 0.67 pounds as compared to 0.8 pounds for the heifers receiving hay. Similarly, Everett et al. (19) reported greater dry matter consumption and average daily gain of heifers fed alfalfa hay than similar heifers fed wilted or direct-cut alfalfa silage. The average daily dry matter intakes by groups were 15.8, 13.8, and 10.4 pounds,

respectively. In like manner, the average daily gains were 1.69, 1.28, and 0.09 pounds. In a second trial, these authors reported no effects on dry matter intake or average daily gain from adding dilute hydrochloric acid to hay (lower pH) or adding Silo-Joy (flavor compound) to the wilted silage. However, they did obtain significant increases in dry matter intake when ground hay was added to the wilted silage which resulted in increased average daily gains of 0.81 pounds. In a third trial, these authors observed no changes in dry matter consumption of silage by increasing the moisture content at time of feeding (adding water) or of hay by adding a dilute solution of acetic acid to the hay in quantities approximating that normally found in silage.

In contrast, Moore et al. (62) reported that wilted silage as the sole roughage for growing dairy calves produced gains equal to those of calves fed barn-cured or field-cured hay when fed at equally controlled levels. Moderate amounts of grain were fed to all groups. Similarly, Porter and Kesler (70) reported comparable gains of dairy calves receiving either hay, grass silage, or grass silage plus hay as their sole roughage source. When silage was the only roughage source, however, the dry matter and TDN intakes were significantly reduced. In a later study, Porter and Kesler (69) studied the effect of feeding young calves high levels

of alfalfa silage with three levels of a calf starter. In general, the feeding of ad libitum quantities of alfalfa silage resulted in growth for the first 16 weeks of life comparable to that obtained on hay or hay plus silage. The calves receiving alfalfa silage consumed slightly less dry matter and TDN than calves receiving alfalfa hay or alfalfa hay and silage.

Wilson and Bartle (92) reported that yearling heifers wintered on alfalfa hay consumed approximately 3.0 pounds more roughage dry matter per day than similar heifers wintered on wilted alfalfa silage (41.1 per cent dry matter). The average daily gains in body weight were 1.36 and 1.23 pounds, respectively. However, the average gain per pound of roughage dry matter consumed was slightly in favor of the silage group (0.125) as compared to the hay group (0.105). Heifers in both groups received 3.0 pounds of grain per heifer daily.

The feeding value of alfalfa stored as baled hay or silage stored in stacks (uncovered), trench silos, and upright silos was compared by McCone and Olson (60). Based on three years work, there were no consistent differences in average daily gains of steers fed any of the above treated forages plus three to seven pounds of grain per day. The three-year average daily gain of steers fed silage from the upright silos was 1.83 pounds as compared to 1.85 for

the group fed hay. Similarly, Flipse et al. (20) reported that bulls receiving four pounds of grass silage per 100 pounds body weight daily increased slightly more in body weight, heart girth, and height at withers than comparable bulls fed equal levels of TDN from grain. Both groups received limited quantities of hay.

Keener et al. (49) compared a clover timothy mixture preserved as silage, mow-dried hay, and field-cured hay taken from the same field at the same stage of maturity. Digestion and energy balance studies showed the field-cured hay to be slightly higher in TDN and metabolizable energy than either the mow-cured hay or silage. The average TDN values on the dry matter basis were 54.5, 57.7, and 59.8 per cent for silage, mow-cured hay, and field-cured hay, respectively. However, when the roughages were fed free choice to dairy heifers with only two pounds of supplemental grain, the heifers receiving silage gained 1.80 pounds per day as compared to 1.16 and 1.26 pounds per day for heifers receiving mow-cured and field-cured hay, respectively. In the same order, the average roughage dry matter intakes were 7.6, 11.7, and 11.4 pounds, respectively. Similarly, Newlander and Riddell (66) observed in two experiments that calves consumed slightly more dry matter from hay than from wilted silage but gained slightly less in body weight. It was also observed in a four-year study that wilted grass

silage (31.6 per cent dry matter) supported greater body weight gains than comparable high moisture silage (22.0 per cent dry matter). Similar trends were observed in dry matter consumption.

In a trial comparing the relative feeding value of corn silage, oat silage, and hay, Lassiter et al. (56) reported that heifers fed hay consumed significantly more dry matter than comparable groups fed either silage. However, the average daily gains were comparable among groups receiving hay or corn silage and significantly higher than heifers fed oat silage. Similar results were reported by McClaugherty and Carter (59) concerning the relative feeding value of wheat silage and corn silage.

Keener et al. (48) raised 24 Holstein and Guernsey calves from a few days to two years of age on milk replacer, 500 pounds of concentrates, and one of four experimental roughage rations: grass silage alone, grass silage plus corn silage (50-50), grass silage plus limited hay, and grass silage plus corn silage (50-50) plus limited hay. In all cases the inclusion of hay in the ration at 0.75 pounds per 100 pounds body weight increased total energy consumption and body weight gains. This observation is not necessarily a measure of the energy value of hay and corn silage but simply points out the preference of these animals for hay. The groups fed grass silage plus hay averaged 94 per cent of

normal at two years of age. All other groups failed to make satisfactory growth during this period.

In contrast, Converse and Wiseman (10) reported results of long-time studies to determine the value of corn silage as the sole roughage for growth of calves and subsequent milk production. Eight heifers (three Holsteins and five Jerseys) were reared from birth and milked through at least one lactation with corn silage as the sole source of roughage. These authors concluded that the heifers exhibited normal growth rates and milk production during the first lactation. The average milk production for Holsteins and Jerseys fed the corn silage ration was 12,149 and 10,316 pounds, respectively. The control animals fed a normal ration (grain, hay, and pasture) averaged 11,406 and 9,585 pounds in the same order. The cows and heifers receiving corn silage were fed somewhat more grain than the control animals. However, all animals were fed to approximately equal the TDN requirements of Savage (76).

Based on the previously cited references, it appears that, in general, both mature and growing dairy cattle consumed more dry matter from hay and heavily wilted silage than from direct-cut silage. However, the animal response in terms of milk production is somewhat more variable than dry matter intake or body weight gain. It appears that some factor(s) in silage has a depressing effect on appetite

which limits dry matter consumption. However, in many cases, indication is given of more efficient utilization of the dry matter consumed from silage than from hay. Thus the relationship of chemical changes during silage fermentation and the feeding value of the resulting silage is in need of further clarification.

Silage Fermentation: Relationship of Preservatives, Microbiological, and Chemical Changes to Feeding Value of Grass Silages

The chemistry and bacteriology of silage fermentation has been reviewed by Watson (89) and more recently by Barnett (4). The use of preservatives in silage fermentation was reviewed by Hillman (32). In general, the following review will consist primarily of recent data pertaining to bacteriological and chemical changes both with and without preservatives and the relationship of these changes to the feeding value of grass silage.

Dufour et al. (16) reported nonsignificant differences in the feeding value of sulfur dioxide silage vs. untreated silage for lactating dairy cows. The average consumption of both groups was 65 pounds per day with average milk production of 25.4 pounds of FCM for the cows fed SO_2 silage and

25.3 pounds for the cows fed untreated silage. Limited quantities of hay and grain were fed to both groups. Similar results were reported by Wittwer et al. (95) concerning the value of molasses, brewers-dried grains, and sodium metabisulfite as preservatives for unwilted hay-crop silage. The feeding values of these silages as well as that of an untreated silage were not significantly different as measured by four per cent FCM, roughage dry matter consumption, and changes in body weight. Limited information concerning the palatability of these silages was reported in which the molasses-treated silage appeared to be the most palatable, whereas the sodium metabisulfite silage was the least palatable.

In contrast to this, Cowan et al. (11) observed that pre-bloom alfalfa when ensiled as either wilted or unwilted without a preservative produced poor quality silage. However, when the same crop was preserved with 8 pounds sodium metabisulfite per ton, the silage was of excellent quality as adjudged by color, odor, lactic acid content, pH, and feeding value. In a second experiment, these authors preserved first cutting alfalfa with 0, 5, 8, 12, and 18 pounds of sodium metabisulfite per ton of fresh forage and found that all treated forages were superior to the untreated but that no improvement was observed from the higher rates of application over five pounds per ton. At the very high levels

of sodium metabisulfite (18 pounds per ton) palatability was adversely affected.

The results of a three-year study conducted by Hardison et al. (28) showed no significant beneficial results as measured by palatability, digestibility, or feeding value from adding sodium metabisulfite or a mixture of urea and molasses to a variety of ensiled forages. There was some indication in this study that Kylage (calcium formate and sodium nitrite) may improve the milk-producing value of grass silage. This, however, was not confirmed in studies by Gordon et al. (23) when Kylage was reported to have little or no effect on nutrient preservation, feeding value, or milk-producing value of hay-crop silage. It was also observed by Hardison et al. (28) that silage treated with either sodium metabisulfite or Kylage exhibited a considerably improved aroma.

Little (57) reported that lactating dairy cows consumed considerably more dry matter and produced slightly more milk from metabisulfite-preserved silage than from untreated silage. The four per cent FCM, butterfat test, and changes in body weight were not significantly different between groups.

Camburn et al. (8) observed that timothy grass silage preserved with phosphoric acid was superior to field-cured timothy hay as a feed for growing dairy heifers. The heifers

receiving silage grew somewhat faster and required slightly less TDN per pound of body weight gain than similar heifers fed hay.

Good preservation of alfalfa forage (20-25 per cent dry matter) was obtained by the addition of sulfuric and hydrochloric acid (A.I.V. method) and molasses as reported by Hegsted et al. (30). When fed to lactating dairy cows, no differences in milk production were observed among groups receiving A.I.V. silage, molasses silage, or corn silage plus linseed meal. Hayden et al. (29), in two trials, observed slightly greater dry matter consumption and milk production when cows were fed A.I.V. silage than when fed hay. For a more complete discussion of the advantages and disadvantages of A.I.V. silage see Watson (89) and Barnett (4).

The use of antibiotics in silage preservation has met with varying degrees of success. Dexter (13) observed that silages preserved with aureomycin, bacitracin, and streptomycin were excellent in odor whereas silages preserved with penicillin and neomycin were undesirable. However, in later work, the results were quite variable and in general no consistent advantage was observed from adding antibiotics to grass silage. Rusoff et al. (75) compared zinc bacitracin (10 gm. per ton), molasses (80 pounds per ton), and sodium metabisulfite (8 pounds per ton) treated silage, and untreated

silage as a feed for lactating dairy cows. Differences among groups as to FCM or efficiency of milk production were not significant. This observation was further substantiated by Pratt and Conrad (71). Similar results were reported by Ramsey et al. (74) where no apparent beneficial results were observed in terms of dry matter intake or digestibility of oat silage from adding zinc bacitracin (five gms. per ton) or Silo-Joy (1.5 pounds per ton).

Some of the earliest and most fruitful investigations concerning alfalfa as a possible silage crop and the relationship of chemical changes and silage quality were made in 1912 and 1913 by Swanson and Tague (82). These authors concluded from their work that alfalfa alone makes good quality silage when finely ground and well packed. However, when coarsely ground and loosely packed, alfalfa made very poor silage. When corn chop was added to the ensiled alfalfa, the resulting product was of such quality that the authors postulated practical realization of this new silage. The fact that silage quality is related to the dry matter content of the ensiled crop was observed in this study. In all cases the addition of water to fresh forage was harmful rather than beneficial. In a second experiment, these authors observed that silage resulting from bud-stage alfalfa (high moisture) was less desirable than silage from more mature alfalfa. Similarly, it was concluded that wilted alfalfa was more suitable for silage making than unwilted alfalfa. These authors

observed that the soluble carbohydrates present in ensiled materials rapidly disappeared with a corresponding increase in acidity. Most of the acidity was encountered during the first two weeks with only slight increases thereafter. No feeding information was collected.

The pH, total volatile acids, and volatile bases of unchopped alfalfa ensiled without a preservative decreased as the dry matter content increased from 19.8 to 33.9 per cent in a study reported by Murdock (63). The lactic acid production was relatively low in all silages but tended to increase from 0.1 to 2.4 per cent as the dry matter content increased from 19.8 to 27.1 per cent. Using different silages, the dry matter consumption of cows increased approximately 2.9 pounds per day as the dry matter content of the silage increased from 18.7 to 26.5 per cent.

Pratt et al. (73) reported that meadow crop silage preserved with 193 pounds of ground corn per ton of green material was somewhat more palatable than untreated meadow crop silage. Similar results were obtained with Kylage, sulfur dioxide, and sodium metabisulfite. Low levels of hay and grain were fed in most cases. In general, palatability declined when less lactic and acetic and more propionic and butyric acids were formed in the silage.

Experiments comparing the quality of alfalfa-timothy silage preserved by wilting or by the addition of 160 pounds

of 2.0 normal glycollic acid, 60 pounds of molasses, or 112 pounds of barley meal per ton of fresh forage were reported by Bailey et al. (2). The pH values were quite similar among groups with a high of pH 4.9 in the wilted silage and a low of pH 4.2 in the glycollic acid silage. The lactic acid contents, however, were quite variable among groups with a high of 7.8 per cent on a dry matter basis in the barley meal-preserved silage and a low of 2.2 per cent in the wilted silage. Butyric acid and volatile bases were quite similar among groups with the exception of the molasses-preserved silage which was somewhat higher in both respects. When the silages were fed on an equal dry matter basis, glycollic acid-preserved silage supported the highest average daily gain of heifers followed in descending order by molasses-treated silage, wilted silage, and barley meal-treated silage. Similar results were obtained by Murdock et al. (64) in comparing the quality of a direct-cut lucerne-timothy mixture ensiled without treatment or preserved with glycollic acid, molasses, barley meal, or formic acid. In general, the resulting pH of the silages were similar among treatment groups but slightly higher for the wilted silage than for the unwilted silage. The lactic acid content of the molasses-treated and barley meal-treated silages were slightly higher than for the other experimental silages. These authors concluded that good quality silage can be made from direct-cut

forage by the addition of glycollic acid, formic acid, and barley meal or by wilting the forage prior to ensiling. Molasses added to the fresh forage resulted in an inferior silage due to the large amounts of volatile bases and butyric acid formed during fermentation.

Kane et al. (47) reported that first cutting orchard grass-ladino clover silage treated with 8.2 pounds of sodium metabisulfite or 5.1 pounds of Kylage showed a lower pH, ammoniacal nitrogen, and butyric acid content than a similar untreated silage. The lactic acid contents were 1.8, 6.2, and 4.9 per cent for the control, metabisulfite, and Kylage-treated silages, respectively. In an 80-day feeding trial, cows consumed approximately 20 per cent more of the treated silages than of the untreated silage. In this study, the dry matter consumption appeared to be positively correlated with high levels of lactic acid and low levels of pH, ammoniacal nitrogen, and butyric acid. Similar results were reported by Gordon et al. (24) where it was observed that Kylage-treated silage was considerably higher in lactic acid and lower in ammoniacal nitrogen and propionic and butyric acids than an untreated direct-cut control silage. The average pH values were 4.52 and 4.98, respectively. When fed to milking cows as the only source of roughage, the average dry matter consumed per 100 pounds body weight were 1.47 and 1.80 pounds per day for the control and Kylage-treated silage

groups, respectively. The following year the same procedure was duplicated without showing any apparent advantage from adding Kylage. In the second year's work the pH, ammoniacal nitrogen, butyric, and lactic acid contents were 3.76, 3.67; 7.5, 6.3; .03, .03; and 7.78 and 8.00 for the untreated and Kylage-treated silages, respectively. The average dry matter consumption values per 100 pounds body weight were 2.01 and 1.96 pounds per day, respectively. This work points out the dominant role played by the control silage in determining what beneficial effects are obtained by using a silage preservative. It is interesting to observe, however, the apparent correlation in this work between lactic acid, butyric acid, and ammoniacal nitrogen and the resulting dry matter consumption of milking cows.

In a later study, Gordon et al. (23) preserved a first cutting, direct-chopped orchard grass and Ladino clover mixture with 200 pounds corn meal per ton of forage or 4.3 pounds of Kylage per ton. These treatments were compared with a control silage (untreated) as to chemical composition and feeding value. The Kylage-treated silage was slightly lower in pH and ammoniacal nitrogen and slightly higher in lactic acid than either of the other two silages. Only traces of propionic and butyric acids were observed in any of the silage treatments. Based on these criteria, all silages were considered to be of good quality. This evaluation was

further substantiated by feeding the experimental forages to lactating dairy cows. The average daily silage dry matter consumption was 2.01, 1.96, and 2.58 pounds per 100 pounds body weight for the control, Kylage-treated, and corn meal-preserved silage, respectively. The increased dry matter consumption of the corn meal-preserved silage could probably be accounted for by the lower grain feeding level of this group (0.34 pounds of grain dry matter per day) as compared to the other groups (7.4 pounds of grain dry matter per day). The lower grain feeding rate probably accounts for a slightly greater rate of decline in milk production of the group fed the corn meal-preserved silage. In a second year's work, recirculated seepage and beet pulp additive were compared with a control silage on the same basis previously mentioned. The recirculated seepage improved the silage quality slightly. However, the added beet pulp increased lactic acid content and dry matter intake considerably. The average daily dry matter intakes were 2.08, 2.06, and 2.58 pounds per 100 pounds body weight for the control, recirculated seepage, and beet pulp-preserved silages, respectively. The 30-day decline in milk production was slightly less for the control group than for either treated silage group.

Murdock et al. (65) ensiled a legume-grass mixture as unchopped, lacerated, unchopped wilted, and chopped wilted

forage and collected samples at 0, 1, 2, 4, 7, and 14 days after ensiling. In general, the pH decreased with time whereas the lactic acid content increased. The final pH values were similar among groups whereas the lactic acid content differed considerably with final values of 5.2, 8.3, and 10.2 per cent of dry matter for the unchopped, chopped, and lacerated silages, respectively. However, in successive trials this trend was not repeated, with the final conclusion that lacerating the forage had little or no effect on the lactic acid content of the silage. In a similar study, Balch et al. (3) compared the chemical changes and digestibility of unchopped, chopped, and lacerated silage. The final pH values were similar among groups, averaging pH 5.1. The lactic acid content was relatively low in all silages, with the chopped silage highest (1.2 per cent of dry matter) and the lacerated silage lowest (0.3 per cent of dry matter). The butyric acid values were 5.0, 3.1, and 1.8 per cent on the dry matter basis and the volatile bases 39.3, 17.1, and 35.6 per cent of the crude protein for the unchopped, chopped, and lacerated silage, respectively. The crude protein, ether extract, and crude fiber contents were lowest in chopped silage, intermediate in lacerated, and highest in unchopped silage. The nitrogen-free extract losses in storage were 49.0, 57.0, and 64.8 per cent in the chopped, lacerated, and unchopped silage, respectively. In the same order,

the average starch equivalents of the dry matter were 50, 47, and 45 pounds, respectively. It is interesting to note in this report that, in general, mature cows had higher digestibility coefficients than steers which indicates the fallacy of determining the feeding value of various feeds with steers, dry cows, or heifers and then applying the data to high-producing dairy cows.

In contrast to the work of Murdock et al. (65) and Balch et al. (3), Gordon et al. (25) observed that forage bruised with a "silorator" resulted in silage lower in pH, ammoniacal nitrogen, and acetic and butyric acids than a chopped control silage. Similarly, the lactic acid content of the bruised silage was 8.02 per cent as compared to 2.01 per cent for the control silage. It was concluded that the higher percentage of ruptured cells in the bruised silage accounted for this difference in chemical composition. However, the mode of action remains an enigma.

In a later study, Gordon et al. (22) compared the chemical constituents and feeding value of alfalfa stored as hay, haylage (heavily wilted silage), and direct-cut silage. In general, only slight differences were observed in roughage dry matter consumption and four per cent FCM production between cows fed direct-cut silage or haylage in two of the three experiments. In one experiment, haylage cows were significantly higher in both respects than cows

receiving direct-cut silage. In general, haylage was considerably lower in ammoniacal nitrogen and organic acids, with the exception of lactic acid, than direct-cut silage. When the various measures of chemical quality were correlated with dry matter intake per 100 pounds of body weight, the correlation coefficients were as follows: pH, -.561; ammoniacal nitrogen as a percentage of total protein, -.890; acetic acid, -.723; propionic acid, -.909; butyric acid, -.723; lactic acid, +.362; and dry matter, +.694. The ammoniacal nitrogen and acetic acid correlations were significant. These data indicate that the criteria used to characterize poor quality silage are better measures of feeding value than the principle criterion of good quality silage (lactic acid) alone. This conclusion was further substantiated by McCullough (61). In this study, the correlation between pH at four days after ensiling and dry matter intake was -0.35. In like manner, the correlation between lactic acid content and dry matter intake was +0.37.

In contrast, Wittwer et al. (94) compared the chemical composition and feeding value of legume-grass forage ensiled as direct-cut, wilted to 25-30 per cent dry matter, and unwilted plus 200 pounds of dry chopped hay per ton of ensiled forage. The average final pH values were quite similar among groups (approximately 4.5). However, the wilted silage and unwilted plus dry hay silage contained slightly

more lactic acid and less acetic and propionic acids than the unwilted silage. When fed to lactating dairy cows, however, differences among groups in dry matter intake, body weight change, or four per cent FCM production were not significant. Similarly, Derbyshire et al. (12) compared silages made from first cutting orchard grass grown on land untreated or treated with 400 pounds of ammonium nitrate per acre. The following values were observed: percentage of crude protein, 14.1, 25.1; ammoniacal nitrogen as per cent of protein, 7.8, 23.2; and pH, 4.0 and 5.1, respectively. In general, the silage resulting from the highly fertilized forage had all the characteristics of poor quality silage. When both silages were fed ad libitum to lactating dairy cows, the average FCM production was 28.8 and 29.4 pounds per day with average daily dry matter consumption of 2.00 and 1.97 pounds for the silage made from the unfertilized and fertilized areas, respectively. In the same order, the average dry matter digestibility was 71.0 and 71.8 per cent, respectively.

Even though it is well known that microorganisms play a very important role in silage fermentation, only limited data are available relating specific classes of microorganisms with particular roles in the fermentation process. In early work on silage fermentation, there was considerable disagreement as to the cause of heat production during the

first few days after ensiling the forage. In 1917, Hunter (45) reported the comparative heat production of glass jars filled with (1) fresh forage, (2) forage treated with weak antiseptic (2-3 per cent chloroform), (3) forage treated with heat, (4) heated forage innoculated with silage bacteria, and (5) cured forage plus water. The untreated fresh, cured, and innoculated forages all produced good silage with normal fermentation, heat production, and organic acid production. The chloroform and heated samples showed no heat or acid production. It was thus concluded that heat production in silage fermentation results primarily from microbial activity and not from intracellular respiration of the plant tissue.

Archibald et al. (1) analyzed 102 lots of green forages and the resulting silages and subjected the results to simple and multiple correlation analysis to determine the influence of the constituents of the green forage on the quality of the resulting silage. The criteria used in evaluating the silage were pH, volatile bases, butyric acid, and lactic acid. High moisture content (75 per cent) was significantly correlated with high butyric acid, pH, and volatile bases. This correlation was not observed when sodium metabisulfite or calcium formate-sodium nitrite additives were used. A positive correlation was observed between sugar content of the forage and lactic acid content of the silage. In general, additives high in sugar or other readily

fermentable carbohydrates (such as molasses, cereal grains, hominy feed, and citrus pulp) gave similar results.

Dobrogosz and Stone (15) determined microbiological counts and chemical changes during active fermentation of untreated silages and silages treated with 8 and 12 pounds of metabisulfite per ton of fresh forage. The microbiological counts as well as the utilization of reducing sugars for organic acid production were in inverse correlation with the amount of metabisulfite added. There were no apparent differences in bacterial cultures between the treated and untreated silages during the active fermentation period. These results show that metabisulfite has a general suppressing effect rather than a selective action on the microbiological population of the silage. Similar conclusions were reported for the action of zinc bacitracin on silage microorganisms (Langston et al., 54).

Alfalfa and orchard grass were stored in small experimental silos by Irvin et al. (46) and subjected to a variety of treatments in an effort to produce several levels of silage quality. The acids studied in each quality of silage were formic, acetic, propionic, butyric, lactic, and succinic. In poor quality silages, acetic and butyric acids were present in large amounts with only small quantities of lactic acid. Butyric acid was present in small amounts after five to eight days and in some cases, later increased up to 4.0

to 6.0 per cent. In general, lactic acid increased quite rapidly for the first five days and then decreased to approximately 1.0 per cent on the dry matter basis. In the good-quality silages lactic acid increased rapidly during the first 8 to 12 days and then leveled off at approximately 8.0 to 9.0 per cent. Butyric acid was absent, or if present, in amounts less than 1.0 per cent. A close relationship was observed between pH and lactic and butyric acid content of the silage. In general, when the pH rose above 4.2 to 4.4, the lactic acid decreased considerably with a corresponding increase in butyric acid. Bacteriological examinations showed an increase in spore-forming anaerobes coinciding with the increase in pH and butyric acid. Two spore-forming groups were isolated; one was proteolytic whereas the other was an active lactate fermenter.

Langston et al. (55) reported studies of 30 different direct-cut silages of varying quality and characterized the good and poor-quality silages as follows: (A) good-quality silage: (1) pH, 3.9 to 4.8; (2) ammoniacal nitrogen (percentage of dry matter), 1.02 to 2.87; (3) butyric acid, 0 to trace amounts; (4) spore counts, erratic but usually contained no spores; and (5) lactic acid (percentage of dry matter), 3.03 to 13.16; and (B) poor-quality silage: (1) pH, 5.2 to 5.7; (2) ammoniacal nitrogen, 3.23 to 9.82; (3) butyric acid, variable but usually high; (4) spore counts, usually high; and (5) lactic acid, showed an initial increase

followed by a decrease with a corresponding increase in butyric acid. Bacteriological examinations showed little correlation between numbers and types of organisms present in good and poor-quality silages when grouped on the basis of total anaerobes and lactic acid bacteria. However, a larger number of anaerobic spore formers were found in the poor-quality silage. When grouped on the basis of homofermentative and heterofermentative rods and cocci, the percentage of heterofermentative rods was higher in good-quality silages. Regardless of the silage quality, all silages tended to increase in rods and decrease in cocci with time. The good-quality silages, however, showed a high initial percentage of cocci as compared to the poor-quality silages. It was suggested that this protocol might be important in establishing proper silage fermentation since it had previously been shown by Pedersen (68) that for proper fermentation in sauerkraut, it was necessary that cocci appear first, closely followed by lactobacilli organisms.

In a later publication, Langston and Bouma (53) reported that in good-quality silage, three species of lactic acid bacteria were predominant: Lactobacillus brevis, Lactobacillus plantarum, and pediococci L. brevis. In poor-quality silage, the three classes previously mentioned plus Lactobacillus casei were observed. The reason for the appearance or the role played by Lactobacillus casei in the poor-quality silage was not evident. It was observed that the

spore-forming anaerobes found in poor-quality silage were able to convert lactate to butyrate, which might explain why the same organisms appear in both silages, but at the same time, a marked difference occurs in lactic acid content of the good and poor-quality silages. Similar results were reported by Kempton and San Clemente (50).

Based on this review, it is apparent that the animal response from feeding direct-cut silage is somewhat more variable and less repeatable than the response from feeding heavily wilted silage or hay. The efficiency of utilization of silage as compared to hay also is quite variable. The chemical changes during silage fermentation appear to be correlated with the acceptability and utilization of the resulting silage. In general, lactic acid content is positively correlated with dry matter intake whereas pH, volatile bases, and propionic and butyric acids are negatively correlated with dry matter intake.

Due to the lack of agreement among the previously cited references as to the feeding value of hay and silage, additional work in this area appeared feasible. The general procedure was to (1) determine the relative feeding value of alfalfa hay and silage taken from the same field, at the same stage of maturity, when fed separately and in combination to lactating dairy cows, (2) compare alfalfa hay and alfalfa silage with and without supplemental grain for lactating

dairy cows, (3) determine the relative feeding value of alfalfa hay and corn silage fed separately and in combination to milking cows, and (4) develop a new process of forage preservation resulting in increased feeding value of stored, direct-cut, legume-grass forage.

EXPERIMENTAL PROCEDURE

During a period of three years, three separate trials were conducted to determine the relative feeding value of legume grass silage and hay for lactating dairy cows. In two of the studies, varying levels of hay and silage were fed ad libitum as the sole source of feed (Experiment I). In the third trial, only hay or silage was fed as the sole source of roughage with and without limited quantities of grain (Experiment II). In all cases the hay and silage were taken from the same field and at the same stage of maturity (approximately one-tenth bloom). Two additional trials were conducted to determine the relative feeding value of corn silage and alfalfa hay when fed singly and in combination to milking cows (Experiment III). In the first portion of Experiment III, grain feeding was corrected for the amount of corn in corn silage, whereas in the second study, the supplemental grain was similar among groups. In both trials supplemental protein was fed to the groups receiving the highest level of corn silage. The principle criteria of evaluation used were: (1) dry matter intake, (2) milk production, and (3) changes in body weight. All feeds were weighed and recorded at the time of feeding. Weigh-backs were taken periodically and deducted from the amount fed. In general, all roughages were fed in slight

excess (approximately 10 per cent) of the amount actually consumed.

In all experiments, the cows were milked twice per day and the milk weighed or measured via a milk-o-meter and recorded. Butterfat determinations were made at regular intervals from three-day composite samples.

All cows were weighed for three consecutive days prior to the beginning of the experiment and at thirty-day intervals thereafter. Dry matter intake per 100 pounds body weight for any particular period was calculated on the basis of the average weight of the animals at the beginning and end of that period unless otherwise stated in the discussion.

Data pertaining to dry matter intake, milk production, and body weight changes were summarized and analyzed statistically according to procedures outlined by Snedecor (81). Significant differences among means were determined according to procedures outlined by May (58).

As pointed out in the review of literature, the results of feeding direct-cut legume grass silage are highly variable and less repeatable than results from feeding hay. In general, the quality of any particular lot of silage may be very good or very poor regardless of whether or not a preservative is used. Therefore, a series of trials were conducted in an attempt to improve the feeding value of legume grass forage

stored in conventional silos (Experiment IV). The preliminary work in this area was conducted in the laboratory where small glass jars were filled with treated forage and stored for various lengths of time to determine any beneficial effects in preservation. One compound which appeared promising was used as an additive to direct-cut alfalfa-brome grass forage stored in small conventional silos. The feeding value of this forage was compared with sodium-metabisulfite treated silage in growth trials with dairy heifers.

Experiment I. Effect of Hay, Silage, and Hay-Silage Combination on Roughage Dry Matter Intake, Milk Production, and Body Weight Change

Two separate trials were conducted to determine the effect of all hay, 75 per cent hay and 25 per cent silage, 50 per cent hay and 50 per cent silage, 25 per cent hay and 75 per cent silage, or all silage rations on dry matter intake, milk production, and body weight change of lactating dairy cows. In 1958, twenty-five Holstein cows were divided into five comparable groups on the basis of milk production, stage of lactation, and body weight and assigned to one of the five experimental rations for a period of 90 days (Hillman, 32). In 1959, this procedure was essentially duplicated giving a total of ten cows per group. Since slight differences

in preliminary milk production occurred among groups in the first year's work, an attempt was made to correct this in the second study.

The hay and silage fed in the second trial were harvested approximately five days later than that used in the first trial. However, in both years, the stage of maturity was estimated to be late-bud to early-bloom. The silage was direct-cut with a forage harvester and ensiled with sodium metabisulfite at the approximate rate of eight pounds per ton of fresh material. The approximate dry matter content of the fresh alfalfa at the time of cutting was 22 per cent in both trials. The hay was cut at the same time as the silage, field-cured, baled, and stored approximately three days after the silage. The hay used in the first trial was put up without rain, whereas that used in the second trial received one very light rain soon after cutting. However, the quality of the hay was considered to be good to excellent. The average chemical composition on a dry matter basis of the hay and silage fed in both years is given in Table 1. The average dry matter content of the silage fed in Trial 1 was slightly lower than that of Trial 2, averaging 22.5 and 24.5 per cent dry matter, respectively.

Since a preference was shown for hay, in essence, the silage was fed ad libitum to all cows with the exception of the all hay group. The amount of hay offered was limited

Table 1

Chemical Composition of Forage Fed in Experiment 1 (D. M. Basis)

Forage	Year	Ash	Crude Fiber	Ether Extract	Crude Protein	N-Free Extract	pH
		%					
Silage	1	8.7	31.2	4.8	17.1	38.1	4.5
	2	8.4	31.9	4.9	19.0	35.6	4.8
Hay	1	6.4	32.2	2.3	17.2	41.9	
	2	6.2	34.0	2.1	19.4	38.3	

to equal its respective part of the total ration. In the first year's study, it was observed that on the average, cows receiving the 75 per cent hay - 25 per cent silage, 50 per cent hay - 50 per cent silage, and 25 per cent hay - 75 per cent silage should be fed 30, 20, and 10 pounds of hay per day, respectively. Therefore, in the second trial, these levels were fed continuously instead of making periodic adjustments in the hay-feeding schedule. All cows were fed their respective ration in slight excess of that actually consumed.

Experiment II. Effect of Hay and Silage, With and Without Supplemental Grain Feeding, on Dry Matter Intake, Milk Production, and Body Weight Change

Fourteen lactating Holstein cows were divided into two balanced groups on the basis of milk production, stage of lactation, and body weight and assigned to either hay or silage ad libitum as the sole source of roughage. Four pairs (four cows in each group) were fed grain on the basis of one pound of grain for each four pounds of milk produced daily during the preliminary period. The other three cows in each group received only roughage. All cows remained on experiment for 120 days.

The hay and silage were harvested from the same field at the same stage of maturity (early-bud stage). The botanical composition was estimated to be approximately 85 per cent alfalfa with the remaining 15 per cent as grass and weeds. The silage was direct-cut and ensiled with eight pounds of metabisulfite per ton of fresh material. The hay was cut at the same time as the silage, field-cured, baled, and stored approximately three days after the silage. The silage was classified as good-quality, whereas the hay was classified as only fair-quality on the basis of color and physical texture. The chemical composition of the hay (sampled by two methods) and silage is given on the dry matter basis in Table 2.

Table 2

Chemical Composition of Hay and Silage Fed in Experiment II (D. M. Basis)

Forage	Sampling Method	Ash	Crude Fiber	Ether Extract	Crude Protein	N-Free Extract
Hay	"Grab"	5.9	39.0	1.0	13.5	40.6
Silage	"Grab"	7.8	32.4	0.4	18.7	40.6
Hay	"Forage Sampler"	---	30.1	---	18.3	----
Silage	"Grab"	---	35.9	---	18.8	----

The first "grab" samples were composites of small quantities of hay and silage taken periodically throughout the experiment. The reason for the apparent difference in chemical composition of the hay and silage is not known. However, based on the high fiber and low protein content of the hay as compared to the silage, some indication is given of excessive leaf loss in this method of sampling. Since a considerable difference in chemical composition occurred, a second set of samples (obtained after completion of the experiment) were analyzed. The chemical composition of the hay sample obtained with the "forage sampler," which was developed at Pennsylvania State College, compared very closely with the two samples of silage. Based on this observation, it appears that hay sampling procedures are quite

critical and that the "forage sampler" may offer a means of obtaining more representative samples of baled hay.

Experiment III. Effect of Hay, Corn Silage, and Hay-Corn Silage Combinations on Dry Matter Intake, Milk Production, and Body Weight Change

Two separate studies were conducted to determine the effect of hay and corn silage, when fed separately and in combination on dry matter intake, milk production, and change in body weight of lactating dairy cows. In the fall of 1958, five cows (four Holstein and one Brown Swiss) were assigned to one of five levels of hay and corn silage and continued on this ration for a period of 84 days. Hay was fed at a rate to approximate 0, 25, 50, 75, and 100 per cent of the total roughage dry matter. Corn silage was fed ad libitum to all cows. Grain was not fed uniformly to all cows since an attempt was made to correct for the amount of corn grain in the corn silage. For each 10 pounds of corn silage consumed, one pound of grain was deducted from the calculated pounds of grain required. The cows on ad libitum silage and 75 per cent silage were fed 2.0 pounds of soybean oil meal per day in place of an equal amount of the regular grain mix. In 1959, this procedure was essentially duplicated with the exception that only three Holstein cows were used per group

and the grain feeding was not corrected for grain supplied by corn silage. In both trials, the amount of grain offered each cow was calculated on the basis of 0.4 pounds of grain for each pound of milk in excess of 16 pounds per day. Grain feeding was decreased at the end of each experimental period on the basis of rate of decline in milk production for all groups.

The hay fed in both trials was first cutting alfalfa and rated good to excellent quality. The grain mix was made up of shelled corn, soybean oil meal, and minerals. The grain mix contained approximately 14.0 per cent crude protein, 2.8 per cent crude fiber, and 78.4 per cent TDN. Each year, corn silage was made from well-eared corn in the early-dent stage. The average dry matter, crude protein, and crude fiber content of the corn silages were 27.0, 27.1; 2.0, 2.4; and 6.4, 5.8 per cent, respectively, for the two years. In the same order, the average pH values were 3.6 and 3.8, respectively. The corn silage was considered to be of good quality in both trials.

Experiment IV. Effect of Organic Solvents in Forage Preservation

During the summer of 1959, a program was initiated to screen antibiotics and organic solvents for possible beneficial value as forage preservatives. In early September,

a series of glass jars were filled with approximately 680 grams of fresh chopped alfalfa which had previously been treated with one of the test products. All jars were immediately sealed and stored for a period of seven months. On April 14, 1960, all jars were opened and the resulting products ranked on the basis of color, smell, and taste. Several members of the dairy staff participated in the judging; and in all cases, a jar containing approximately three per cent ethanol was considered quite superior in all three previously listed criteria. The results were considered adequate to warrant further investigation of the product in terms of animal response.

During the summer of 1960, three experimental concrete stave silos (12 feet by 12 feet) were filled with direct-cut second-cutting alfalfa taken from the same field. The material in Silo 1 was preserved with eight pounds of sodium metabisulfite per ton. A specially denatured alcohol (4.26 gallons of ethyl acetate per 100 gallons) was added to silos 2 and 3 at the rate of 20 pounds per ton in Silo 2 and 60 pounds per ton in Silo 3. Following a 35-day fermentation period, the silos were opened and the resulting product fed to three comparable groups (six animals per group) of Holstein heifers for a period of 30 days.

During the growth trial, all heifers were fed one of the three experimental forages ad libitum. No supplemental

feed was offered. Daily forage consumption was determined by weighing the amount offered and subtracting the amount each animal refused. All animals were weighed at the beginning of the trial and every 15 days thereafter.

The dry matter content of the ensiled forages was 23.0, 20.3, and 21.6 per cent for silos 1, 2, and 3, respectively. In like manner, the crude protein and crude fiber values were 20.8, 31.6; 18.6, 34.5; and 19.8, 33.3 per cent, respectively. The forage preserved in silos 2 and 3 was cut approximately one week after that of silo 1. The slightly lower dry matter content of this forage was probably due to rainy weather during this period. The later date of cutting was evidenced by a slightly lower protein and slightly higher crude fiber content of the forage. The pH values were 5.1, 4.6, and 4.8, respectively, for silos 1, 2, and 3.

Additional studies were made comparing the effects of adding various organic solvents to direct-cut alfalfa stored in small glass jars. The criteria used in evaluating the forages were organic acid production, gas production with time, pH, and human preference tests based on color, smell, and taste. The organic acids were determined by the method of Wiseman and Irvin (93).

RESULTS AND DISCUSSION

Experiment I. Effect of Hay, Silage, and Hay-Silage Combinations on Roughage Dry Matter Intake, Milk Production, and Body Weight Change

In both trials of Experiment I, cows receiving all-hay rations consumed more total roughage dry matter than cows receiving all-silage rations. During Trial 1, the total roughage dry matter consumption increased from 26.2 pounds per day to 41.0 pounds per day, as the level of hay in the ration increased from 0 to 100 per cent. In Trial 2, the same trend was observed. However, cows receiving 75 per cent hay and 25 per cent silage rations consumed slightly more total dry matter than cows receiving the all-hay ration. In general, cows consumed slightly more total dry matter per day on all rations in Trial 1 than in Trial 2. (Table 3). Similarly, the same trend was observed in dry matter consumption per 100 pounds body weight (Table 4). When the dry matter consumption per 100 pounds body weight in Trial 1 was analyzed statistically, it was observed that cows on the all-hay ration consumed significantly more dry matter than similar cows fed all-silage or 75 per cent silage ($P < 0.01$) and more than those fed 50 per cent silage and 25 per cent silage ($P < 0.05$). The 75 per cent and 50 per cent hay groups consumed more dry matter than the all-silage groups ($P < 0.05$).

Table 3

Average Daily Dry Matter Intake of Cows Fed Hay, Silage, or Hay-Silage Combinations Ad Libitum by 30-Day Periods for Two Trials (Experiment I)

Ration	Period I Trial 1	Period I Trial 2	Period II Trial 1	Period II Trial 2	Period III Trial 1	Period III Trial 2	Average for both Trials
	lb.	lb.	lb.	lb.	lb.	lb.	lb.
All Silage	27.1	25.1	26.7	26.0	24.9	25.3	25.8
75 Per Cent Silage	29.1	23.1	28.2	24.7	28.3	26.2	26.6
50 Per Cent Silage	32.0	31.0	33.2	31.2	33.3	31.4	32.0
25 Per Cent Silage	34.8	37.1	35.5	35.9	35.1	36.6	35.8
All Hay	38.2	34.4	41.5	34.5	43.2	34.6	37.7
Average	31.2		31.7		31.9		

Table 4

Average Daily Dry Matter Intake and Dry Matter Intake per 100 Pounds Body Weight (Experiment I)

Ration	DRY MATTER INTAKE				
	Per Day		Per 100 lb. B. W.		Average Per 100 lb. B. W.
	Trial 1	Trial 2	Trial 1	Trial 2	
	lb.	lb.	lb.	lb.	lb.
All Silage	26.2	25.4	2.46	2.08	2.27[a]
75% Silage	28.6	24.7	2.70	2.28	2.49[b]
50% Silage	32.8	31.2	2.97	2.77	2.87[c]
25% Silage	35.1	36.6	2.99	3.21	3.10[d]
All Hay	41.0	34.5	3.52	2.94	3.23[e]

c, d, and e > a ($P < 0.05$)
d and e > b ($P < 0.05$)

In the second trial, the average pounds of dry matter consumed per 100 pounds body weight were 2.08, 2.28, 2.77, 3.21, and 2.94 for the all silage, 25 per cent hay, 50 per cent hay, 75 per cent hay, and all hay groups, respectively. In this trial, the 75 per cent hay group consumed significantly ($P < 0.01$) more dry matter than any other group. In like manner, the 50 per cent hay group and all hay group consumed significantly ($P < 0.01$) more dry matter than the 25 per cent hay group and the all silage group. Differences between the all silage group and the 25 per cent hay group and between the 50 per cent hay group and

the all hay group were not significant. However, in both cases significance was approached at the five per cent level of probability.

When the two trials were combined, the average daily dry matter consumption per 100 pounds body weight was 2.27, 2.49, 2.87, 3.10, and 3.23 pounds for the all silage, 25 per cent hay, 50 per cent hay, 75 per cent hay, and all hay groups, respectively. In Table 5, the analysis of variance summary is given for the two trials.

Table 5

Analysis of Variance Table of Dry Matter Consumption (Experiment I)

Source	d.f.	Sum of Squares	Mean Square
Total	49	11.560	
Rations	4	6.710	1.678
Trials	1	.885	.885
RxT	4	.920	.230
Residual	40	3.045	.076

Since in Trial 1, the all hay group consumed considerably more dry matter than the 75 per cent hay group, but in Trial 2 the reverse was true, the ration x trial interaction becomes significant ($P < 0.05$). Therefore, if these data are to be interpreted and utilized to predict

future results, the significant interaction must be used as the error term for testing ration and trial effects. When this term is used as the error term instead of the residual variance, the significance of rations is reduced from ($P < 0.01$) to ($P < 0.05$) and the difference between trials is non significant. In these terms, the all hay group, 75 per cent hay group, and 50 per cent hay group, consumed significantly ($P < 0.05$) more dry matter per 100 pounds body weight than the all silage group. Similarly, the all hay group and 75 per cent hay group consumed significantly more dry matter than the 25 per cent hay group. No other differences among means were statistically significant.

In the first year's study (Trial 1), the average milk production per cow tended to follow the same trend as dry matter consumption. In other words, cows on the all hay, 75 per cent hay, and 50 per cent hay rations produced somewhat more milk than cows on the all silage and 75 per cent silage rations. This trend was not repeated in Trial 2. The average milk production for both trials is given in Table 6.

When the two trials were combined the average milk production per cow was slightly higher on the all hay, 75 per cent hay and 50 per cent hay rations than on the all silage or 75 per cent silage rations. When statistically analyzed, no significant differences among groups were

Table 6

Average Milk Production Per Day by Rations and 30-Day Periods for Trials 1 and 2 (Experiment I)

Ration	Trial	Prel. Milk	Period I	Period II	Period III	Ave. for 2 Trials
		lb.	lb.	lb.	lb.	lb.
All Silage	1	36.8	33.1	29.0	25.1	30.4
	2	45.9	34.6	32.1	28.7	
75% Silage	1	34.1	31.8	28.4	25.4	30.1
	2	46.8	35.3	31.3	28.2	
50% Silage	1	37.4	35.3	31.0	29.8	31.2
	2	45.4	33.4	29.4	28.5	
25% Silage	1	39.5	35.8	33.0	28.1	31.4
	2	44.4	33.3	30.4	28.1	
All Hay	1	37.5	33.9	32.6	30.4	31.2
	2	47.1	34.6	29.1	26.4	
Average		41.5	34.1	30.6	27.9	

observed due to rations or years (Trial 1 versus Trial 2). In fact, the variance in total milk production between trials was very slight, which indicates that the total milk production on all rations was quite similar in both trials. The only significant difference observed in milk production was among periods, which is simply a measure of the decreased milk production as lactation progresses. Therefore, it is evident that even though cows consumed more dry matter as the level of hay in the ration increased, the extra dry

matter consumed did not result in increased milk production. This fact is further substantiated by the average persistency of milk production as shown in Table 7.

Table 7

Average 30-Day Persistency Values by Rations and Periods for Trials 1 and 2

Ration	Trial	Period I	Period II	Period III	Ave. for 2 Trials
		lb.	lb.	lb.	lb.
All Silage	1	86.8	89.2	88.3	86.4
	2	71.2	95.5	87.2	
75% Silage	1	88.0	87.3	95.4	86.7
	2	72.3	89.7	87.4	
50% Silage	1	88.7	92.1	97.0	89.4
	2	68.2	97.0	93.2	
25% Silage	1	87.6	91.0	86.0	86.8
	2	72.2	92.2	91.8	
All Hay	1	90.9	96.4	94.0	87.3
	2	68.4	88.4	85.5	
Average		79.4	91.9	90.6	

The average 30-day persistency values in Trial 1 were calculated by dividing the average pounds of milk produced per day by each group during the last 10 days of the previous period into the average pounds of milk produced during the last 10 days of the period in question. In Trial 2, the last 7 days of the period were used instead of the last

10 days. In general, the average persistency values by rations were relatively close among groups and did not appear to be directly related to the level of hay in the ration. It is interesting to observe the significant ($P < 0.01$) difference among periods. The average persistency of period I was considerably lower than periods II and III. When tables 6 and 7 are compared, it appears that the all roughage rations were not sufficient to maintain the level of milk produced during the preliminary period (41.5 pounds), and thus all cows showed a considerable decline in production to the level produced during period I (34.1 pounds). The average persistency values after this initial drop were approximately normal for the expected decline in milk production due to advancing stage of lactation. The average persistency values in Trial 1 were somewhat higher than those in Trial 2. However, the major differences were observed in period I. A portion of this difference can probably be explained on the basis of a higher initial production and thus a greater decline to the level of production supported by the all-roughage ration. The average level of initial production in Trial 1 was 37.1 pounds as compared to 45.9 pounds for Trial 2. Based on the results obtained in both trials, it appears that all roughage rations consisting of all silage, all hay, or combinations of silage and hay will only support milk production of Holstein cows at approximately 30 to 34 pounds per day.

In Trial 1, the gain in body weight appeared to be closely related to the level of hay in the ration. The average daily changes in body weight of cows fed the five experimental rations were as follows: all silage, -0.64 pounds; 75% silage, -0.22 pounds; 50% silage, -0.06 pounds; 25% silage, +0.57 pounds; and all hay, +0.26 pounds. The differences among groups were not significant. However, significance was approached at the five per cent level of probability. In Trial 2, the same trend was observed in average change in body weight as in Trial 1. The average daily gain and loss of body weight per cow by treatment groups were as follows: all silage, -0.89; 75% silage, -0.88; 50% silage, -0.05; 25% silage, +0.18; and all hay, +0.04 pounds for the 90-day period. The differences among groups due to rations were not significant. However, there was a definite trend for body weight gain to increase as the level of hay in the ration increased. The average 90-day body weight changes for both trials are given in Table 8.

When the data from both trials were combined the changes in body weight followed dry matter consumption very closely down to the 25 per cent silage - 75 per cent hay group. However, when tables 4 and 8 are compared it will be observed that the all-hay group consumed slightly more dry matter, but gained less body weight, than the 75 per cent hay group.

Table 8

Average 90-Day Body Weight Change by Rations and Trials

Ration	Trial 1	Trial 2	Average
	lb.	lb.	lb.
All Silage	-58.0	-80.2	-69.1
75% Silage	-20.0	-79.1	-49.6
50% Silage	- 5.0	- 4.3	- 4.6
25% Silage	+51.0	+16.7	+33.8
All Hay	+23.0	+ 3.5	+13.2

This experiment was not designed to determine the efficiency of dry matter utilization of cows fed hay and silage, however, the question is always of interest and these data give some information of this nature. To determine the efficiency of utilization, dry matter consumption, milk production per day, and change in body weight must all be considered. In Table 9, the average daily dry matter consumed per 100 pounds body weight, FCM production, and body weight changes are given by rations for both trials.

When the two trials were combined the average daily FCM production increased as the dry matter intake per 100 pounds body weight increased. When compared on the basis of FCM produced per pound of dry matter consumed, the efficiency of dry matter utilization was considerably greater for the all-silage group than for the all-hay group. However,

Table 9

Average Daily Dry Matter Intake per 100 Pounds Body Weight, FCM Production and Body Weight Change for Trials 1 and 2

Ration	Dry Matter Intake	FCM Production	Body Weight Change
	lb.	lb.	lb.
All Silage	2.27	27.6	-0.76
75% Silage	2.49	27.6	-0.55
50% Silage	2.87	28.6	-0.06
25% Silage	3.10	29.4	+0.38
All Hay	3.23	29.4	+0.15

in a comparison such as this, the change in body weight has not been considered. Therefore, some correction must be made for gain or loss of body weight. The TDN or energy value of one pound of body weight loss is not known. However, with the limitations of this calculation fully in mind, the values of 3.53 pounds of TDN per pound of body weight gain and 2.73 pounds of TDN per pound of body weight loss were employed (Knott et al., 52). The estimated pounds of FCM were calculated on the basis of a 1200-pound Holstein cow requiring 8.0 pounds of TDN daily for maintenance. An average value of 55.0 per cent TDN on the dry basis was used for both silage and hay. The amount of TDN required per pound of four per cent milk was 0.32 pounds. These values were used to calculate the theoretical production possible

from the ingested forage and then compared to the actual production (Table 10).

Table 10

Calculated Production on the Basis of Dry Matter Consumption Versus Actual Production by Ration Groups

Ration	Calculated Production	Actual Production	Difference Calculated-Actual
	lb./day	lb./day	lb./day
All Silage	28.3	27.6	0.7
75% Silage	31.0	27.6	3.4
50% Silage	34.7	28.6	6.1
25% Silage	34.8	29.4	5.4
All Hay	40.0	29.4	10.6

The results shown in Table 10 indicate that in general the differences between the calculated production and actual production of FCM increased as the level of hay in the ration increased from 0 to 100 per cent. Since the changes in body weight were converted to a FCM equivalent basis, this increased difference suggests less efficient utilization of the all-hay ration than of the all-silage ration. An estimate of gross efficiency corrected for body weight change was made and presented in Table 11. The dry matter intake was adjusted for change in body weight and the efficiency of dry matter utilization calculated by dividing the

corrected daily dry matter intake into the daily FCM production. The same average correction constants were used in this calculation as used in calculating the theoretical FCM production.

Table 11

Efficiency of Utilization of Silage and Hay for Milk Production with Dry Matter Intake Corrected for Body Weight Change

Ration	Corrected D.M. Intake		FCM	Milk/D.M.
	D.M./100 lb.	D.M./day	lb./day	lb./lb.
All Silage	2.58	31.0	27.6	0.89
75% Silage	2.72	32.6	27.6	0.85
50% Silage	2.89	34.7	28.6	0.82
25% Silage	2.90	34.8	29.4	0.84
All Hay	3.15	37.8	29.4	0.78

When no consideration was given for maintenance requirements, cows on the all-silage ration produced 0.89 pounds of FCM per pound of adjusted dry matter as compared to 0.78 pounds of FCM for the all-hay group.

A comparison of net efficiency was made by converting forage dry matter consumption to a TDN basis, subtracting a maintenance value and dividing the FCM production by the adjusted intake. The net amount of TDN required per pound of FCM was 0.33 and 0.44 pounds for the all-silage and all-hay groups, respectively. The different hay-silage combinations

were in between these ranges and tended to increase as the level of hay in the rations increased. However, the 25 per cent silage group had a slightly higher net efficiency than the 50 per cent silage group.

Based on the results of two trials, it appears that dry matter consumption increases as the level of hay in the ration increases. Milk production and body weight change follow a pattern similar to dry matter intake. However, when total dry matter consumption is compared to milk production response, with corrections for body weight change, the efficiency of dry matter utilization appears to decrease as the level of hay in the ration increases. Additional studies, employing controlled feeding practices, will be necessary to further elucidate this point.

Experiment II. Effect of Hay and Silage, With and Without Supplemental Grain Feeding, on Dry Matter Intake, Milk Production and Body Weight Change

In Experiment II, 14 Holstein cows were paired on the basis of milk production, body weight, stage of lactation, and age and assigned to either hay or silage as the sole source of roughage. Four pairs of cows were fed limited grain, whereas, the remaining three pairs were fed only roughage. The average preliminary milk production data and grain feeding schedules are shown in Table 12.

Table 12

Average Daily Preliminary Milk Production and Grain Feeding Schedule in Experiment II

Group	Prelim. Milk	Hay	Silage	Ratio Grain to Milk
	lb.			
1	41.6	ad lib.	------	---
1A	42.9	ad lib.	------	1:4
2	42.8	------	ad lib.	---
2A	44.2	------	ad lib.	1:4

As mentioned previously, the hay and silage were harvested from the same field and at the same stage of maturity. The chemical analyses of both forages are shown in Table 2.

Grain was fed at a constant rate throughout the 120-day experimental period. In all cases, hay and silage were fed in slight excess of that actually consumed.

Forage consumption data are given by groups and periods in Table 13.

When either hay or silage was fed as the sole source of roughage, limited grain feeding decreased forage consumption slightly. The average decrease in hay consumption for the 120-day period was approximately 3.6 pounds as compared to an average decrease of 13.2 pounds in silage consumption. When compared on a dry matter basis, the decreased roughage intake attributable to grain feeding was approximately equal.

Table 13

Average Daily Forage Consumption by Groups and 30-Day Periods

Group	Period I	II	III	IV	Av.
	lb.	lb.	lb.	lb.	lb.
1--ad lib. Hay	30.3	32.2	32.8	33.4	32.2
1A--ad lib. Hay + Grain	28.8	28.6	28.5	28.5	28.6
2--ad lib. Silage	100.6	108.9	107.5	108.6	106.4
2A--ad lib. Silage + Grain	94.3	91.8	92.4	94.3	93.2

The average daily forage dry matter consumption is given in Table 14 by ration groups and periods.

Table 14

Average Daily Forage Dry Matter Consumption by Groups and Periods

Group	Period I	II	III	IV	Av.
	lb.	lb.	lb.	lb.	lb.
1--ad lib. Hay	26.3	27.8	28.3	29.1	27.9
1A--ad lib. Hay + Grain	25.1	24.4	24.4	25.1	24.8
2--ad lib. Silage	23.4	27.6	26.5	26.6	26.0
2A--ad lib. Silage + Grain	22.4	23.6	23.6	23.2	23.2

The average dry matter consumption from hay was 26.4 as compared to 24.6 pounds from silage. Similarly, the

average roughage dry matter consumption of cows fed only roughage was 27.0 as compared to 24.0 for cows fed roughage plus grain. When analyzed statistically, it was observed that cows consumed significantly ($P < 0.01$) more dry matter from hay than from silage. In like manner, cows fed grain consumed significantly ($P < 0.01$) less dry matter from either roughage than cows not fed grain. However, when total dry matter consumption was considered (roughage dry matter + grain dry matter), cows fed grain consumed significantly ($P < 0.01$) more total dry matter than cows not fed grain. It was also observed that cows fed hay consumed more total dry matter than cows fed silage ($P < 0.05$). Cows fed hay plus grain consumed 8.9 pounds of grain dry matter per day as compared to 9.2 pounds for cows fed silage plus grain. In all analyses, there were no significant forage x grain interactions which indicates that grain feeding had similar effects on dry matter consumption when fed with either forage.

Total roughage dry matter per 100 pounds body weight was calculated for each individual cow and statistically analyzed by groups and periods. The body weight values at the beginning and end of each 30-day experimental period were averaged and used in calculating roughage dry matter consumption per 100 pounds body weight. When analyzed on this basis, no significant differences were observed among

groups due to the forage fed. However, the effect of feeding grain was significant ($P < 0.01$). Later when the body weight data were calculated, it was observed that cows receiving hay gained somewhat more in body weight than cows receiving silage. Therefore, the dry matter intake per 100 pounds body weight as previously calculated was confounded with the change in body weight. The dry matter intakes per 100 pounds body weight were recalculated on the basis of beginning body weight only and are presented in Table 15.

Table 15

Average Daily Roughage Dry Matter Intake Per 100 Pounds Beginning Body Weight

Group	Period I	II	III	IV	Av.
	lb.	lb.	lb.	lb.	lb.
1--ad lib. Hay	2.41	2.54	2.58	2.66	2.55
1A--ad lib. Hay + Grain	2.17	2.11	2.10	2.17	2.14
2--ad lib. Silage	2.16	2.55	2.45	2.47	2.41
2A--ad lib. Silage + Grain	1.96	2.06	2.07	2.04	2.03

Based on beginning body weights, the average roughage dry matter consumption per 100 pounds body weight was 2.31 from hay and 2.19 pounds from silage. Similarly, the average roughage dry matter consumption of cows fed grain was 2.08, as compared to 2.48 pounds for cows not fed grain.

When analyzed statistically, cows consumed significantly ($P < 0.05$) more roughage dry matter per 100 pounds body weight from hay than from silage. In like manner, cows fed grain consumed significantly ($P < 0.01$) less dry matter from hay or silage than cows not fed grain.

The preliminary milk production of cows fed hay was 42.3 pounds per day as compared to 43.6 pounds per day for cows fed silage (Table 12). The average daily milk production by rations for the 120-day experimental period is given in Table 16.

Table 16

Average Daily Milk Production by Rations and Periods for the 120-Day Experimental Period

Group	Period I	II	III	IV	Av.
	lb.	lb.	lb.	lb.	lb.
1--ad lib. Hay	30.8	25.7	24.0	22.8	25.8
1A--ad lib. Hay + Grain	38.8	33.2	29.4	25.8	31.8
2--ad lib. Silage	34.0	31.5	28.8	25.4	29.9
2A--ad lib. Silage + Grain	41.7	40.1	37.3	35.0	38.5

The average daily milk production of cows fed hay was 29.2 pounds as compared to 34.8 pounds for cows fed silage. In like manner, the average daily milk production of cows

fed only roughage was 27.8 pounds as compared to 35.2 pounds for cows fed roughage plus grain. When groups receiving grain were combined, the average grain dry matter consumed per day was 9.0 pounds, with an increased milk yield of 7.4 pounds. However, this comparison does not take into consideration any change in body weight. It is interesting to note that a greater response was obtained from feeding grain to cows consuming silage than to cows consuming hay. When analyzed statistically, it was observed that cows fed silage produced significantly ($P < 0.01$) more milk or FCM than cows fed hay. Similarly, cows fed roughage plus grain produced significantly more milk than cows fed only roughage ($P < 0.01$). It was also observed that cows receiving silage were significantly ($P < 0.05$) more persistent in milk production (91.6%) than cows receiving hay (86.7%). The higher milk production of cows fed silage as compared to those fed hay is not in agreement with results obtained in Experiment I.

The average change in body weight per cow for each 30-day period is given by ration groups in Table 17.

Both groups fed hay gained in body weight during the 120-day experimental period. The group receiving grain gained approximately 63 pounds more per cow than the group fed only hay. In the silage-fed groups, only the one fed grain gained in body weight, whereas the other group lost

Table 17

Average Change in Body Weight Per Cow by Groups and Periods

Group	Period I	Period II	Period III	Period IV	Total Change
	lb.	lb.	lb.	lb.	lb.
1--ad lib. Hay	+17.2	+19.1	-18.5	- 4.8	+13.0
1A--ad lib. Hay + Grain	+13.3	+21.5	+20.4	+20.7	+75.9
2--ad lib. Silage	-20.4	+10.1	-30.8	+24.9	-16.2
2A--ad lib. Silage + Grain	-16.3	+27.6	+ 5.5	+32.3	+49.1

approximately 16 pounds per cow. In both cases greater average body weight gains were made when grain was fed in addition to either roughage. The average daily gain of cows fed hay was 0.41 as compared to 0.18 pounds for cows fed silage. When statistically analyzed, no significant differences were observed among groups due to kind of forage. It was observed, however, that grain feeding significantly increased body weight gain of cows fed either hay or silage.

In Table 18, the average daily dry matter consumption, FCM production, and body weight change are given for Groups 1, 2, 3, and 4, respectively.

When assuming an average weight of 1200 pounds per cow and the roughage groups are combined, 1.0 pound of grain dry matter replaced 0.56 pound of roughage dry matter and produced an additional 0.82 pound of four per cent FCM and

Table 18

Average Daily Dry Matter Consumption, FCM Production, and Body Weight Change of Cows Fed Hay and Silage With and Without Supplemental Grain

Group	Roughage D. M. Per 100 lb. Av. B. W.	Grain D. M.	FCM	Body Wt. Change
	lb.	lb.	lb.	lb.
1--ad lib. Hay	2.49	0.0	24.1	+0.11
1A--ad lib. Hay + Grain	2.08	8.9	29.6	+0.63
2--ad lib. Silage	2.45	0.0	27.4	-0.14
2A--ad lib. Silage + Grain	2.02	9.2	36.7	+0.41
Roughage	2.47	0.0	25.8	-0.01
Roughage + Grain	2.05	9.0	33.2	+0.52

and 0.06 pound of body weight gain per day. Gross efficiency of dry matter utilization (calculated as outlined in Experiment I) was highest for the group receiving silage plus grain and lowest for the group receiving only hay. The average pounds of FCM produced per pound of dry matter consumed were 0.82, 0.99, 0.91, and 1.19 pounds, respectively, for groups 1, 2, 3, and 4. The average pounds of TDN required per pound of FCM were 0.34 for the all-hay group and 0.31 for the all-silage group. In both cases silage was more efficiently utilized than hay for milk production.

Based on these results and under the conditions of this experiment, it appears that cows consume less dry matter from silage than from hay. However, cows consuming silage, with and without supplemental grain, produced more milk than similar cows fed hay, with and without supplemental grain. Grain feeding significantly decreased dry matter intake from silage and hay but significantly increased total dry matter consumption. Similarly, grain feeding increased FCM production and body weight gain of cows fed either hay or silage.

Experiment III. Effect of Hay, Corn Silage, and Hay-Corn Silage Combinations on Dry Matter Intake, Milk Production, and Body Weight Change

In this experiment, two separate trials were conducted to determine the relative feeding value of hay and corn silage when fed separately and in combination to lactating dairy cows. In the first trial, grain feeding was corrected for the amount of grain in corn silage on the basis of 1.0 pound of corn grain for each 10.0 pounds of corn silage (Huffman et al., 43). In the second trial, this correction was not made. In both trials, hay was limited to 0.0, 10.0, 20.0, and 30.0 pounds per cow per day, whereas, corn silage was fed ad libitum. A fifth group received hay ad libitum as the only source of roughage.

The average roughage dry matter consumption, and total dry matter consumption per day and per 100 pounds body weight during Trial 1 are given in Table 19.

In general, the total roughage dry matter and total dry matter increased as the level of hay in the ration increased. This trend was more marked in the case of total dry matter, which is probably the result of decreased quantities of supplemental grain fed, as the level of corn silage consumption increased. The average daily rate of supplemental grain feeding was 4.8, 5.3, 5.2, 7.2, and 11.3 pounds per cow for groups 1, 2, 3, 4, and 5, respectively. When analyzed

Table 19

Average Roughage Dry Matter Consumption and Total Dry Matter Consumption Per Day and Per 100 Pounds Body Weight During Trial 1 (Experiment III)

D. M. Consumption	RATION GROUP 1	2	3	4	5
	Corn Sil.	Corn Sil. + 10 lb. Hay	Corn Sil. + 20 lb. Hay	Corn Sil. + 30 lb. Hay	All Hay
	lb.	lb.	lb.	lb.	lb.
Total Roughage D.M./Day	27.0	29.6	31.4	31.2	31.2
Total D.M./Day	31.4	34.6	35.6	37.8	40.5
Roughage D.M./100 lb. B.W.	1.94	2.06	2.35	2.30	2.38
Total D.M./100 lb. B.W.	2.27	2.40	2.67	2.78	3.09

statistically, it was observed that ration groups 2, 3, 4, and 5 consumed significantly ($P < 0.01$) more total roughage dry matter than group 1 (all corn silage group). Similarly, ration groups 3, 4, and 5 consumed significantly ($P < 0.05$) more roughage dry matter than group 2 (ad lib. corn silage plus 10 lb. hay). Differences among groups receiving rations containing 20 and 30 lb. hay or all-hay were not significant. When roughage dry matter consumption was based on body weight, it was observed that ration groups 3, 4, and 5 consumed significantly ($P < 0.01$) more dry matter than groups 1 and 2. However, significance was approached at the five per cent level of probability between groups 1 and 2 in roughage dry matter consumption per 100 pounds body weight. When comparing total dry matter intake per 100 pounds body weight, groups 3, 4, and 5 consumed significantly ($P < 0.01$) more total dry matter per 100 pounds body weight than group 1. In this trial, roughage dry matter consumption followed a similar trend as observed in Experiment I, where hay and grass silage were compared singly and in combination. The increased total dry matter consumption from feeding supplemental grain is in agreement with results reported in Experiment II.

In Trial 2, the experimental procedure was the same as Trial 1 with the exception that all cows were fed grain at the same rate. In other words, no correction was made for the amount of grain supplied in the corn silage.

The average roughage dry matter consumption and total dry matter consumption data are given in Table 20.

The dry matter intake of cows in Trial 2 followed the same pattern as that observed in Trial 1. However, since only three cows per group were used in Trial 2, the average values of dry matter consumption were quite variable. The exceptionally high average dry matter intake of Group 4 was primarily due to two cows in that group which consumed very large quantities of corn silage. It should also be pointed out that since Trial 2 was conducted to supplement Trial 1, the cows were grouped so as to give similar values for beginning milk production among treatment groups for both trials. In other words, if one particular treatment group was lowest in milk production during the preliminary period of Trial 1, then the highest producing group was placed on that treatment in Trial 2. As mentioned previously, grain was fed according to milk production. The average level of grain feeding for the 90-day trial was 9.7, 7.7, 9.8, 13.0, and 11.7 pounds for groups 1, 2, 3, 4, and 5, respectively. The slightly higher rate of grain feeding would partially explain the higher rate of total dry matter consumption by group 4, but certainly would not explain the higher rate of dry matter consumption from roughage.

When these data were analyzed, it was observed that cows on ration 4 consumed significantly ($P < 0.01$) more

Table 20

Average Roughage Dry Matter Consumption and Total Dry Matter Consumption Per Day and Per 100 Pounds Body Weight During Trial II

D. M. Consumption	RATION GROUP 1 Corn Sil.	2 Corn Sil. + 10 lb. Hay	3 Corn Sil. + 20 lb. Hay	4 Corn Sil. + 30 lb. Hay	5 All Hay
	lb.	lb.	lb.	lb.	lb.
Total Roughage D.M./Day	23.4	28.8	29.8	39.9	29.9
Total D.M./Day	32.0	35.6	38.5	51.3	40.2
Roughage D.M./100 lb. B.W.	1.62	2.09	2.26	2.93	2.26
Total D.M./100 lb. B.W.	2.24	2.58	2.91	3.79	3.07

roughage dry matter than any other experimental group. The group receiving only corn silage consumed significantly less roughage dry matter than groups 3 and 5 ($P < 0.01$) and less than 2 ($P < 0.05$). The same statistical conclusions were obtained when roughage dry matter consumption was calculated on a per 100 pound body weight basis, except that ration groups 5 and 3 consumed significantly ($P < 0.05$) more dry matter on this basis, than group 2. When total dry matter intake was compared among groups, it was observed that the group receiving 30 pounds of hay per day consumed significantly ($P < 0.01$) more total dry matter than all other groups. Similarly, the all-hay group and the 20 pound hay group consumed significantly more total dry matter than the all-silage group. Differences between the all-silage group and 10 pound hay group were not significant. However, significance was approached at the five per cent level of probability.

In both trials, the addition of hay to an all corn silage-limited grain ration increased roughage dry matter intake and total dry matter intake per cow per day. The two years' data were combined and the average roughage dry matter intake and total dry matter intake per 100 pounds body weight are shown in Table 21.

When the combined data for Trials 1 and 2 were statistically analyzed, Group 4 consumed significantly more

Table 21

Average Roughage Dry Matter Intake and Total Dry Matter Intake Per 100 Pounds Body Weight for Both Trials

Group	Dry Matter Intake/100 Lb. B. W.	
	Roughage	Total
	lb.	lb.
1 (All Silage)	1.82	2.26
2 (Silage + 10 lb. Hay)	2.07	2.47
3 (Silage + 20 lb. Hay)	2.31	2.76
4 (Silage + 30 lb. Hay)	2.53	3.16
5 (All Hay)	2.34	3.08

roughage dry matter than all other groups ($P < 0.01$). Similarly, groups 2, 3, and 5 consumed significantly more roughage dry matter than group 1 ($P < 0.01$). The differences between groups 3 and 5 were not significant, however, both were significantly higher in roughage dry matter consumption than group 2 ($P < 0.01$). A summary of the analysis of variance for the combined data is given in Table 22.

It is interesting to note the small difference between trials even though grain was fed at two different levels, which indicates that grain level has a much smaller effect than hay on total roughage consumption. This observation is further substantiated by the small period effect, which indicates that cows consumed similar quantities of

Table 22

Analysis of Variance Table for Roughage Dry Matter Consumption Per 100 Pounds Body Weight for Both Trials

Source	d.f.	Sum of Squares	Mean Square
Total	119	14.84	
Rations	4	7.15	1.79
Periods	2	0.16	0.08
Trials	1	0.01	0.01
Residual	112	7.52	0.067

roughage dry matter in all periods, even though less grain was fed in each successive period. As mentioned in the experimental procedure, grain was decreased each period on the basis of average rate of decline in milk production for all groups.

No significant differences were observed among groups in milk production during Trial 1 or Trial 2. Therefore, in order to conserve space, the combined milk production data for both trials are given in Table 23.

When the combined milk production data for the two trials were statistically analyzed, the differences among group means due to rations were not significant. It was observed, however, that when the data were combined, there was a significant ($P < 0.05$) difference in average milk production for all cows between trials. Cows in Trial 2,

Table 23

Average Daily Milk Production Per Cow by Ration Groups and Periods for Both Trials

Group	Prelim. Prod.	Period 1	Period 2	Period 3	Av.
	lb.	lb.	lb.	lb.	lb.
1 (All Silage)	44.6	39.8	36.2	32.2	36.1
2 (Silage + 10 lb. Hay)	43.4	41.2	37.6	35.9	38.2
3 (Silage + 20 lb. Hay)	40.1	38.8	34.2	31.1	34.7
4 (Silage + 30 lb. Hay)	42.0	39.4	36.0	32.7	36.0
5 (All Hay)	43.9	38.8	35.4	30.0	34.8

produced significantly more milk on all rations than cows in Trial 1. The average daily milk production was 34.0 and 39.2 pounds for Trials 1 and 2, respectively. The average preliminary milk weights were slightly higher in Trial 2 than in Trial 1. However, the differences in grain feeding level probably attributed to the higher level of milk production in the second trial. When milk production was converted to a four per cent FCM basis, differences among ration groups were not significant. However, as might be expected, a significant period difference was observed which is simply a measure of the normal decline in milk production as stage of lactation progresses. In general, the trends observed in comparing groups as to FCM production were the

same as those observed in comparisons made on the uncorrected basis.

The average persistency values for Trials 1 and 2 are shown in Table 24. When these data were analyzed separately, no significant differences were observed among groups due to rations.

Table 24

Average Persistency of Milk Production by Rations and Periods for Both Trials

Group	PERSISTENCY			
	Period			
	I	II	III	Average
	%	%	%	%
1 (ad lib. Silage)	84.4	90.6	85.4	86.8
2 (Silage + 10 lb. Hay)	94.3	90.8	93.9	93.0
3 (Silage + 20 lb. Hay)	91.9	89.0	88.7	89.9
4 (Silage + 30 lb. Hay)	90.8	90.2	86.1	89.0
5 (All Hay)	86.2	88.5	83.3	86.0
Trial 1 Average	89.2	87.6	87.6	88.2
Trial 2 Average	90.0	93.5	87.3	90.3

Due to considerable variation in persistency of cows within groups, no significant differences were observed among rations. The average persistency of cows receiving all corn silage or all hay were quite similar but slightly

below that of cows receiving any combination of silage and hay. The persistency data support the conclusions from total milk production in that no significant differences were observed among rations in either case. The average persistency of milk production was slightly higher in Trial 2 than in Trial 1. This difference was not significant, but was in agreement with average milk production for the two trials. This observation lends further support to the fact that the additional grain fed in Trial 2 resulted in slightly higher milk production, irrespective of treatments.

The average change in body weight per cow for each period was analyzed statistically by trials. In both trials, the differences among groups due to rations were not statistically significant. It was observed, however, that in both cases there was a significant period effect. The average daily gains for each trial by periods are given in Table 25.

The changes in body weight by periods were somewhat unusual in that greater body weight gains were made in period 1 than in periods 2 and 3. The same trend was observed in both trials regardless of ration. In Trial 1, however, the cows receiving higher levels of silage appeared to gain somewhat less in period 3 than cows receiving ad lib. hay. In Trial 2, when supplemental grain was fed on an equal basis, this trend was reversed. When body weight data for

Table 25

Average Daily Change in Body Weight by Ration Groups and Periods

Group	Period 1		Period 2		Period 3		Av.
	1	2	1	2	1	2	
	lb.	lb.	lb.	lb.	lb.	lb.	lb.
1 (All Silage)	1.61	1.96	1.30	1.16	-0.11	1.21	1.19
2 (Silage + 10 lb. Hay)	2.25	2.09	1.09	1.04	0.01	1.33	1.30
3 (Silage + 20 lb. Hay)	1.61	2.67	0.28	0.85	0.56	1.52	1.25
4 (Silage + 30 lb. Hay)	1.10	1.90	1.97	1.01	0.76	0.59	1.22
5 (All Hay)	1.34	2.75	1.08	0.79	1.55	0.35	1.31
Average	1.58	2.27	1.14	0.97	0.55	1.00	

the two trials were combined, the differences among ration groups were not significant. It was observed, however, that the period x trial interaction was significant ($P < 0.05$). As shown in Table 25, cows in Trial 2 irrespective of ration gained more in body weight during periods 1 and 3 than cows in Trial 1, whereas during period 2 the reverse situation was observed. Due to the significant period x trial interaction, the differences among periods were not significant when the data were combined for both trials. It is difficult to explain the greater gain in body weight during period 1 than during periods 2 and 3, since in both trials the total dry matter consumption remained relatively constant for all three periods. When calculated on the basis of dry matter intake per 100 pounds body weight, however, the dry matter consumption decreased as the trial progressed. Some additional feed would be required for the increased body weight maintenance during the latter periods. However, as discussed previously, milk production decreased as the trial progressed which should more than counter-balance any increase in maintenance requirements. The difference in body weight gain between trials was not significant. However, somewhat greater average daily gains were observed in Trial 2 than in Trial 1. This is probably associated with the high levels of supplemental grain feeding employed in Trial 2.

Based on the results of these two trials, it appears that cows consume more roughage dry matter from hay than from

corn silage. However, only slight differences occurred in dry matter consumption among groups receiving ad lib. hay, 20 pounds of hay plus corn silage, or 30 pounds of hay plus corn silage. The increased dry matter consumption by these groups did not result in increased milk production. A difference in milk production between trials was observed which indicated slightly greater milk yields with increased grain feeding. No significant differences in persistency of milk production were observed among ration groups which further supports the milk production data.

Experiment IV. Effect of Organic Solvents on Forage Preservation

Preliminary observations had indicated beneficial effects from adding small quantities of 95 per cent ethanol to direct-cut alfalfa stored in glass jars. Therefore, a larger scale experiment was designed to determine any changes in feeding value of forage preserved with two levels of denatured ethanol as compared to the same forage preserved with sodium metabisulfite. For this evaluation a 30-day growth trial with Holstein heifers was conducted and the results are shown in Table 26.

The data presented in Table 26 are interesting from several view points. The ethanol-treated forages were

Table 26

Effect of Forage Treatment on Dry Matter Consumption, Growth, and Feed Efficiency of Growing Dairy Heifers

	Silo 1 Metabisulfite	Silo 2 1% Ethanol	Silo 3 3% Ethanol
	lb.	lb.	lb.
Initial body weight	818.5	810.2	804.7
30-Day Gain	30.6	43.5	50.5
Av. Daily Gain	1.02*	1.45	1.68
Daily D. M. Consumed	14.0	13.2	13.7
Gain Per 100 lb. D. M.	7.28	10.98	12.26

* Significant ($P < 0.05$).

harvested approximately one week after the sodium metabisulfite-treated forage which resulted in approximately 1.5 per cent less crude protein and 2.3 per cent more crude fiber than the metabisulfite-treated forage. Therefore, on an equal dry matter basis, greater body weight gains would have been expected for heifers receiving the metabisulfite-treated forage. However, as shown in Table 25 these heifers gained approximately 0.5 pounds less than heifers fed the ethanol-treated forages. Differences among groups in roughage dry matter consumption were small which indicates little or no effect of ethanol on acceptability of the forage. An increased efficiency of dry matter utilization from the ethanol-treated forage was evident since the two ethanol-treated

forages supported higher weight gains than the metabisulfite-treated forage while dry matter consumption remained relatively constant. When efficiency was calculated on the basis of pounds of gain per 100 pounds of dry matter consumed, the resulting values were 7.28, 10.98, and 12.26 pounds for heifers receiving the metabisulfite-treated forage, 1.0 per cent ethanol-treated forage, and 3.0 per cent ethanol-treated forage, respectively. Without question, the addition of ethanol to the forage supplied some additional energy. However, it was observed that a major portion of the ethanol was lost within the first 30 days after ensiling. At the end of 77 days, the forage in Silo 2 contained only 0.2 per cent ethanol whereas the forage in Silo 3 contained only 0.4 per cent. The exact contribution of the ethanol as an energy source in this trial cannot be determined. However, regardless of what values are used for the energy content and efficiency of utilization of the ethanol, only a small portion of the increased gain of heifers receiving the ethanol-treated forage can be explained on that basis.

Additional studies were conducted to determine the effect of adding small quantities of ethanol, ethyl acetate, formalin, butyl alcohol, and acetone on the fermentation of direct-cut alfalfa stored in small glass jars (Table 27).

In general, lactic and succinic acids were slightly higher in the ethanol and butanol-treated forages than in any of the other treated forages. The butyric acid content

Table 27

Organic Acids, Gas Production, pH, and Preference Test of Forages Stored in Glass Jars with Various Additives

Treatment	Micro M Acid/g. D.M. Butyric	Acetic	Lactic + Succinic	Ml. Gas 70 hrs.	pH	Preference Test
Control	7	609	949	940	4.5	+++
ETOH (1%)	5	738	1086	805	4.5	++
ETOH (2%)	5	551	1044	---	4.4	+++
Ethyl Acetate (3%)	8	1172	869	---	4.1	++
Formalin (1%)	8	52	62	---	5.5	++++
Butyl Alc. (1%)	22	549	1006	---	4.5	+
Acetone (1%)	7	825	820	---	4.5	+++

was relatively low in all forages with the exception of the forage-treated with 1.0 per cent butyl alcohol. Similarly, the forage treated with ethyl acetate was somewhat higher in acetic acid than all other experimental forages. It is interesting to note the organic acid content, pH, and preference test of the forage treated with 1.0 per cent formalin. This forage was characterized by low levels of all organic acids and a resulting high pH. The preference test score was highest for this treatment due to the pleasing aroma, color, and taste of the forage. The general appearance and aroma of the formalin-treated forage was very similar to fresh-cut forage. The mode of action of the formalin is not presently known but it appears to have had a general bacteriostatic effect with only slight fermentation occurring during storage. The pH values were quite similar among other experimental forage treatments. The gas production during the first 70 hours of storage indicated that 1.0 per cent ethanol slightly depressed initial gas production. However, the exact mode of action of ethanol and other organic solvents in forage preservation remains unknown. Based on human preference test the formalin-treated forage was ranked highest followed by the control forage (no additive), ethanol (2.0%) treated forage and acetone (1.0%) treated forage.

Based on these studies it appears that (1) ethanol preservation increases the feeding value of ensiled

direct-cut forage and (2) that fermentation can be altered by adding small quantities of formalin, ethanol, and other organic solvents.

SUMMARY

Two separate trials were conducted to determine the relative feeding value of alfalfa hay, alfalfa silage, and combinations of alfalfa hay and silage as the sole source of feed for lactating dairy cows. A third trial was conducted to determine the effect of feeding supplemental grain to cows on all-silage and all-hay rations. In all three trials, the hay and silage were harvested from the same field and at the same stage of maturity. In a similar experiment, two separate trials were conducted to determine the relative feeding value of good-quality alfalfa hay and corn silage when fed separately and in combination to lactating dairy cows. A fifth study was conducted in an attempt to improve the feeding value of direct-cut alfalfa forage stored in conventional silos.

In the first two trials, it was observed that cows consumed significantly ($P < 0.01$) more dry matter from hay than from silage. In general, the dry matter consumption increased as the amount of hay in the ration increased. When data from the two trials were combined and statistically analyzed, it was observed that cows fed all hay, 75 per cent hay, and 50 per cent hay rations consumed significantly ($P < 0.05$) more dry matter than similar cows fed all-silage rations. In the first trial, milk production followed a

similar trend as dry matter consumption, however, when the two trials were combined the differences among ration groups in milk production were not significant. Therefore, it is evident that even though cows consumed more dry matter from hay than from silage the extra dry matter did not result in increased milk production. This fact was further substantiated by similarity among groups in persistency of milk production. It was observed that cows gained somewhat more in body weight as the level of hay in the ration and dry matter consumption increased. When the efficiency of dry matter utilization was calculated, it was observed that dry matter from silage was more efficiently utilized for milk production, than dry matter from hay.

When cows were fed supplemental grain in addition to ad libitum silage or hay, it was found that cows consumed significantly less dry matter from silage than from hay ($P < 0.01$). Supplemental grain feeding reduced dry matter consumption from either hay or silage ($P < 0.01$). However, when total dry matter consumption was considered, cows fed grain consumed significantly ($P < 0.01$) more dry matter than cows not fed grain. In like manner, cows fed grain produced significantly more FCM ($P < 0.01$) and gained more in body weight ($P < 0.05$) than cows fed all-roughage rations. In this study, cows fed silage produced significantly ($P < 0.01$) more milk than cows fed hay.

When alfalfa hay and corn silage were fed singly and in combination to lactating dairy cows, the roughage dry matter consumption generally increased as the level of hay in the ration increased. Cows fed corn silage ad libitum consumed significantly ($P < 0.01$) less roughage dry matter than cows fed 20 or more pounds of hay per day. The differences among groups in milk production were not significant. Similarly, no significant differences were observed among groups in persistency of milk production or gain in body weight. The average gain in body weight was slightly less for cows receiving corn silage as the only source of roughage than for cows receiving limited quantities of hay or hay ad libitum. Since significantly more dry matter was consumed from rations containing hay than from an all corn silage ration, whereas differences in milk production and body weight gain were not significant, it appears that a pound of dry matter from corn silage was more efficiently utilized than a pound of dry matter from hay.

Preliminary observations in the laboratory indicated beneficial effects of adding small quantities of 95 per cent ethanol to direct-cut alfalfa stored in glass jars. It was later observed that heifers fed 1.0 and 3.0 per cent ethanol preserved forage gained approximately 0.5 pounds more per day than heifers fed sodium metabisulfite-treated forage. The daily dry matter consumption was similar among groups, averaging 14.0, 13.2, and 13.7 pounds per heifer for the

metabisulfite, 1.0 per cent ethanol and 3.0 per cent ethanol preserved forage, respectively. In the same order the pounds of body weight gain per 100 pounds of dry matter were 7.28, 10.98, and 12.26 pounds, respectively. The exact mode of action of the ethanol is not known. Based on this work, however, ethanol-preserved forage appears to be higher in feeding value than similar forage preserved with metabisulfite.

Preliminary observations were made with formalin, ethyl acetate, butyl alcohol, and acetone as preservatives for storing direct-cut alfalfa. Based on human preference tests, acetone and formalin appeared promising. Additional work is in progress to further elucidate the mode of action of formalin, ethanol, acetone, and other organic solvents in forage preservation.

LITERATURE CITED

1. Archibald, J. G., J. W. Kusmeski, and S. Russell. Grass Silage Quality as Affected by Crop Composition and by Additives. J. Dairy Sci. 43:1648. 1960.

2. Bailey, G. L., C. C. Balch, and J. C. Murdock. The Digestibility and Feeding Value of a Lucerne Timothy Sward Ensiled in Four Ways. J. British Grassland Soc. 10:1.

3. Balch, C. C., J. C. Murdock, and J. Turner. The Effect of Chopping and Lacerating Before Ensiling on the Digestibility of Silage by Cows and Steers. J. British Grassland Soc. 10:326. 1955.

4. Barnett, A. J. G. Silage Fermentation. New York Academic Press, Inc. Publishers. New York 10, New York. 1954.

5. Bender, G. B. and H. H. Tucker. Timothy Silage as a Dairy Feed. N. J. Agr. Expt. Sta. Cir. 374. 1937.

6. Blosser, T. H., G. W. Porter, R. E. Lintott, H. P. Shaw, and U. S. Ashworth. The Use of Large Amounts of Silage in the Dairy Ration. Wash. Agr. Expt. Sta. Cir. 20. 1952.

7. Breirem, Knut, Thor Homb, Knut Presthegge, and Ola Ulvesli. Some Results from 15 Years Research on Grassland Products in the Feeding of Ruminants. Meldinger Fra Norges Landbrukshogskale. Vol. 38, No. 9. 1959.

8. Camburn, O. M., H. B. Ellenberger, and C. H. Jones. Feeding Values of Silages and Hays. Vermont Agr. Expt. Sta. Bul. 482. 1942.

9. Cobble, J. W. and Glenn Wildes. Grass-Legume Silage as the Sole Roughage for Lactating Dairy Cows. J. Dairy Sci. 39:938. 1956.

10. Converse, H. T. and H. G. Wiseman. Corn Silage as the Sole Roughage for Dairy Cattle. U.S.D.A. Tech. Bul. 1057. 1952.

11. Cowan, R. L., J. W. Bratzler, E. Keck, Jr., R. W. Swift, G. Alderman, and J. B. Washko. Further Experiments with Sodium Bisulfite as a Preservative for Grass Silage. J. Animal Sci. 15:1188. 1956.

12. Derbyshire, J. C., C. H. Gordon, H. G. Wiseman, C. G. Melin, and E. A. Kane. Chemical Quality and Feeding Value of Orchard Grass Silage as Affected by Nitrogen Fertilization. J. Dairy Sci. 44:1175. 1961.

13. Dexter, S. T. The Use of Antibiotics in Making of Silage. Agron. J. 49:483. 1957.

14. Dijkstra, N. D. Silage Als Enig Ruwvoeder Voor Melkvee. Versl. Landbouwk. Onderz. 65:14. 1959.

15. Dobrogosz, W. J. and R. W. Stone. Microbiological and Chemical Studies on Metabisulfite Treated Silage. Bacteriological Proceedings, p. 23. 1957.

16. Dufour, L., R. P. Niedermeier, C. E. Zehner, and J. W. Crowley. Sulfur Dioxide as a Preservative for High Moisture Legume Silage. J. Dairy Sci. 37:52. 1954.

17. Dunn, K. M., R. E. Ely, C. F. Huffman, and C. W. Duncan. The Value of Snapped Corn-Ear Silage and Grainless Corn Silage (ears removed) for Milk Production. Mich. Agr. Expt. Sta. Quart. Bul. 37:223. 1954.

18. Ely, R. E., L. G. Schoenleber, J. B. Shepherd, H. G. Wiseman, C. G. Melin, W. H. Hosterman, and R. E. Wagner. Conservation of Nutrients and Feeding Value of Wilted Silage, Barn-cured Hay, and Dehydrated Hay. J. Dairy Sci. 32:716. 1949.

19. Everett, J. P., C. A. Lassiter, C. F. Huffman, and C. W. Duncan. The Effect of Various Additives on Dry Matter Intake of Heifers Fed Either Alfalfa Silage or Hay. J. Dairy Sci. 41:721. 1958.

20. Flipse, R. J., D. L. Thacker, and J. O. Almquist. Effects of Feeding Large Amounts of Grass Silage to Dairy Bulls on Feed Utilization, Body Measurements, and Semen Quality. J. Dairy Sci. 35:949-956. 1952.

21. Gordon, C. H., J. C. Derbyshire, C. G. Melin, E. A. Kane, J. F. Sykes, and D. T. Black. Consumption and Feeding Value of Silages as Affected by Dry Matter Content. J. Dairy Sci. 43:866. 1960.

22. Gordon, C. H., J. C. Derbyshire, H. G. Wiseman, E. A. Kane, and C. G. Melin. Preservation and Feeding Value of Alfalfa Stored as Hay, Haylage, and Direct-cut Silage. J. Dairy Sci. 44:1299. 1961.

23. Gordon, C. H., H. M. Irvin, C. G. Melin, H. G. Wiseman, and J. R. McCalmont. Some Experiments in Preservation of High-Moisture Hay-Crop Silages. J. Dairy Sci. 40:789. 1957.

24. Gordon, C. H., C. G. Melin, H. M. Irvin, H. G. Wiseman, and L. E. Campbell. Variability in the Quality of Untreated High-Moisture Silages. J. Dairy Sci. 38:624. 1955.

25. Gordon, C. H., H. G. Wiseman, J. C. Derbyshire, W. C. Jacobson, and D. T. Black. Effect on Silage of Chopping and Bruising the Forage. J. Dairy Sci. 42:1394. 1959.

26. Graves, R. R., J. R. Dawson, and D. V. Kopland. Relative Values for Milk Production of Hay and Silage Made from Immature Pasture Herbage. U.S.D.A. Tech. Bul. 649. 1938.

27. Graves, R. R., J. R. Dawson, D. V. Kopland, and T. W. Moseley. Feeding Value for Milk Production of Pasture Grasses When Grazed, When Fed Green, and When Fed as Hay or Silage. U.S.D.A. Tech. Bul. 381. 1933.

28. Hardison, W. A., W. N. Linkous, R. A. Sandy, G. C. Graf, and R. W. Engel. The effect of Preservatives on the Feeding Value of Grass Silage. Va. Agr. Expt. Sta. Res. Rpt. No. 7. 1957.

29. Hayden, C. C., A. E. Perkins, C. F. Monroe, W. E. Krows, R. C. Washburn, and C. E. Knox. Hay Crop Silage - A Summary of Ten Years Work. Ohio Agr. Expt. Sta. Bul. 656. 1945.

30. Hegsted, D. M., F. W. Quackenbush, W. H. Peterson, G. Bohstedt, I. W. Rupel, and W. A. King. A Comparison of Alfalfa Silages Prepared by the AIV and Molasses Methods. J. Dairy Sci. 22:489. 1939.

31. Hill, D. L., B. J. Walker, and N. S. Lundquist. Grass Silage as the Only Source of Nutrients for Milking Cows. J. Animal Sci. 13:1008. 1954.

32. Hillman, D. Appetite Studies in Dairy Cattle: Grass Silage vs. Hay. Ph.D. Thesis, Michigan State University Library, East Lansing, Michigan. 1959.

33. Hillman, D., Lassiter, C. A. Huffman, C. F., and C. W. Duncan. Effect of All-Hay vs. All-Silage Rations on Dry Matter Intake of Lactating Dairy Cows; Moisture and pH as Factors Affecting Appetite. J. Dairy Sci. 41:720. 1958.

34. Hodgson, R. E. and J. C. Knott. The Feeding Value of Alfalfa Hay Compared with Mixed Hay and Grass Silage as a Ration for Dairy Cattle. Wash. Agr. Expt. Sta. Bul. 386. 1940.

35. Horwood, R. E. and J. G. Wells, Jr. Alfalfa-Molasses Silage vs. Alfalfa-hay as a Roughage for Lactating Dairy Cows. Mich. Agr. Expt. Sta. Quart. Bul. 19:2. 1936.

36. Huffman, C. F. Roughage Quality and Quantity in the Dairy Ration. A Review. J. Dairy Sci. 11.889. 1939.

37. Huffman, C. F. Summer Feeding of Dairy Cattle. A Review. J. Dairy Sci. 42:1495. 1959.

38. Huffman, C. F., S. T. Dexter, and C. W. Duncan. The Feeding Value of Pea and Oat Silage for Dairy Cows. Mich. Agr. Expt. Sta. Bul. 36:298. 1954.

39. Huffman, C. F., S. T. Dexter, R. M. Grimes, and C. W. Duncan. The Digestibility and Feeding Value of Ladino Clover Silage for Dairy Cattle. Mich. Agr. Expt. Sta. Bul. 29:444. 1957.

40. Huffman, C. F. and C. W. Duncan. Corn Silage as a Source of the Unidentified Grain Factor(s) Needed for Milk Production. Mich. Agr. Expt. Sta. Quart. Bul. 37:23. 1954.

41. Huffman, C. F. and C. W. Duncan. Comparison of Silages Made from Field Corn (Ohio M-15) and Silage Corn (Eureka) for Milk Production. J. Dairy Sci. 39:998. 1956.

42. Huffman, C. F. and C. W. Duncan. Chemical Composition, Coefficients of Digestibility and Total Digestible Nutrient Content of Corn Silages. Mich. Agr. Expt. Sta. Quart. Bul. 43:261. 1960.

43. Huffman, C. F., C. W. Duncan, and S. T. Dexter. Corn Grain and Stalks (Hay Equivalent) in Corn Silages Obtained from Random Samples. Mich. Agr. Expt. Sta. Quart. Bul. 42:801. 1960.

44. Huffman, C. F., C. W. Duncan, and R. M. Grimes. Grain Equivalent Value of Prebud Alfalfa Hay and Alfalfa-Rye-Grass Silage in Respect to Milk Production. Mich. Agr. Expt. Sta. Bul. 39:241. 1956.

45. Hunter, O. W. Microorganisms and Heat Production in Silage Fermentation. J. Agr. Res. 10:75. 1917.

46. Irvin, H. M., C. W. Langston, and C. H. Gordon. Development of Organic Acids in Silage. J. Dairy Sci. 39:940. 1956.

47. Kane, E. A., W. C. Jacobson, C. H. Gordon, and P. M. Domewood, Jr. Effect of Chemical Silage Conditioners on Digestibility of Silage. J. Dairy Sci. 39:939. 1956. Also See U.S.D.A.-ARS-52-32. 1956.

48. Keener, H. A., F. E. Allen, N. F. Colovos, Ann C. Paul, and H. A. Davis. Value of Adding Corn Silage and Limited Quantities of Hay to a Grass Silage, Limited Grain Ration for Dairy Heifers. J. Dairy Sci. 41:429-437. 1958.

49. Keener, H. A., N. F. Colovos, K. S. Morrow, G. M. Foulkrod, G. P. Percival, and J. R. Prescott. The Relative Feeding Value of a Forage Preserved by Ensiling, Mow Curing, and Field Curing. N. H. Agr. Expt. Sta. Cir. 77. 1949.

50. Kempton, A. G. and C. L. San Clemente. Chemistry and Microbiology of Forage-Crop Silage. Appl. Microbiol. 7:362. 1959.

51. Keyes, E. A. and E. P. Smith. The Feeding Value of Alfalfa for Dairy Cows When Harvested and Stored by Four Different Methods. Mont. Agr. Expt. Sta. Bul. 513. 1955.

52. Knott, J. C., R. E. Hodgson, and E. V. Ellington. Methods of Measuring Pasture Yields with Dairy Cattle. Wash. Agr. Expt. Sta. Bul. 295. 1934.

53. Langston, C. W. and C. Bouma. Types and Sequence Change of Bacteria in Orchard Grass and Alfalfa Silages. J. Dairy Sci. 43:1575. 1960.

54. Langston, C. W., R. M. Conner, C. H. Gordon, and L. A. Moore. The Effect of Zinc Bacitracin on Silage Microorganisms. J. Dairy Sci. 44:1204. 1961.

55. Langston, C. W., H. Irvin, C. H. Gordon, C. Bouma, H. G. Wiseman, C. G. Melin, L. A. Moore, and J. R. McCalmont. Microbiology and Chemistry of Grass Silage. U.S.D.A. Tech. Bul. 1187. 1958.

56. Lassiter, C. A., C. F. Huffman, S. T. Dexter, and C. W. Duncan. Corn Versus Oat Silages as a Roughage for Dairy Cattle. J. Dairy Sci. 41:1282. 1958.

57. Little, C. J. Hay Crop Silage Treated with Sodium Metabisulfite for Winter Feeding of Dairy Cows. Mich. Agr. Expt. Sta. Quart. Bul. 38:252. 1955.

58. May, J. M. Extended and Corrected Tables of the Upper Percentage Points of the "Studentized" Range. Biometrika 39:192. 1952.

59. McClaugherty, F. S. and R. C. Carter. Small Grain vs. Corn Silage for Wintering Beef Calves. Va. Agr. Expt. Sta. Bul. 512. 1960.

60. McCone, W. C. and O. E. Olson. Alfalfa-Silage - Effect of Storage Methods on Feeding Values and on Preservation of Nutrients. S. D. Agr. Expt. Sta. Bul. 479. 1959.

61. McCullough, M. E. A Study of Factors Associated with Silage Fermentation and Dry Matter Intake by Dairy Cows. J. Animal Sci. 20:288. 1961.

62. Moore, L. A., J. W. Thomas, W. C. Jacobson, C. G. Melin, and J. B. Shephard. Comparative Antirachitic Value of Field-Cured Hay, Barn-Dried Hay, and Wilted Grass Silage for Growing Dairy Calves. J. Dairy Sci. 31:489. 1948.

63. Murdoch, J. C. The Effect of Pre-Wilting Herbage on the Composition of Silage and Its Intake by Cows. Jour. of the Brit. Grassland Soc. 15:70. 1960.

64. Murdoch, J. C., D. A. Balch, A. S. Foot, and S. J. Rowland. The Ensiling of Lucerne with Addition of Formic and Glycollic Acids, Molasses and Barley Meal and with Wilting. J. British Grassland Soc. 10:139. 1955.

65. Murdoch, J. C., D. A. Balch, M. C. Holdsworth, and M. Wood. The Effect of Chopping, Lacerating, and Wilting of Herbage on the Chemical Composition of Silage. J. British Grassland Soc. 10:181. 1955.

66. Newlander, J. A. and W. H. Riddell. High-Moisture versus Wilted Grass Silage for Raising Dairy Calves. Vt. Agr. Expt. Sta. Bul. 602. 1957.

67. Nicholson, J. W. and R. C. Parent. Various Combinations of Grass Silage and Hay for Dairy Cattle. Canadian J. Animal Sci., 37:64. 1957.

68. Pederson, C. S. The effect of Pure Culture Inoculation on the Quality and Chemical Composition of Sauerkraut. N. Y. State Agr. Exp. Sta. Tech. Bul. 169. 1930.

69. Porter, G. H. and E. M. Kesler. Value of Alfalfa Silage in the Diet of the Young Dairy Calf. J. Dairy Sci. 40:163. 1957.

70. Porter, G. H. and Kesler, E. M. The Value of Grass Silage in the Diet of the Young Dairy Calf. J. Animal Sci. 13:1010. 1954.

71. Pratt, A. D. and H. R. Conrad. Zinc Bacitracin as a Silage Preservative. J. Dairy Sci. 44:1205. 1961.

72. Pratt, A. D. and H. R. Conrad. Proportions of Hay and Silage in the Dairy Ration. J. Dairy Sci. 40:620. 1957.

73. Pratt, A. D., R. C. Washburn and C. F. Rogers. Comparative Palatabilities of Silages. Ohio Agr. Expt. Sta. Res. Bul. 814. 1958.

74. Ramsey, D. S., J. W. Lusk, and J. T. Miles. Oat Forage for Hay or silage. Miss. Agr. Expt. Sta. Inf. Sheet 659. 1960.

75. Rusoff, L. L., C. P. Breidenstein, and J. B. Frye. Value of Bacitracin as a Preservative for Grass Silage on Milk Production. J. Dairy Sci. 42:929. 1959.

76. Savage, E. S. A Study of Feeding Standards for Milk Production. Cornell Agr. Expt. Sta. Bul. 323. 1912.

77. Shepherd, J. B., C. H. Gordon, H. G. Wiseman, and C. G. Melin. Comparisons of Silages Stored in Gas-Tight Silos and in Conventional Silos. J. Dairy Sci. 36:1190. 1953.

78. Shepherd, J. B., H. G. Wiseman, R. E. Ely, C. G. Melin, W. J. Sweetman, C. H. Gordon, L. G. Schoenleber, R. E. Wagner, L. E. Campbell, G. D. Roane, and W. H. Hosterman. Relative Merits of Four Methods of Harvesting and Preserving Alfalfa Forage for Dairy Feed. U.S.D.A. Cir. 963. 1955.

79. Shepherd, J. B., W. G. Wiseman, R. E. Melin, W. J. Sweetman, C. H. Gordon, L. G. Schoenleber, R. E. Wagner, L. E. Campbell, G. D. Koone, and W. H. Hosterman. Experiments in Harvesting and Preserving Alfalfa for Dairy Cattle. U.S.D.A. Tech. Bul. 1079. 1954.

80. Slack, S. T., W. K. Kennedy, K. L. Turk, J. T. Reid, and G. W. Trimberger. Effect of Curing Methods and Stage of Maturity Upon Feeding Value of Roughages. Part 2. Different Levels of Grain. Cornell Expt. Sta. Bul. 957. 1960.

81. Snedecor, G. W. Statistical Methods, 5th ed., The Iowa State College Press, Ames, Iowa. 1956.

82. Swanson, C. O. and E. L. Tague. Chemical Studies in Making Alfalfa Silage. J. Agr. Res. 10:275. 1917.

83. Sykes, J. F., L. A. Moore, and H. T. Converse. Comparison of Alfalfa Hay and Wilted Silage as a Roughage for Growing Dairy Heifers. J. Dairy Sci. 38:613. 1955.

84. Thomas, J. W., J. F. Sykes, and L. A. Moore. Comparison of Alfalfa Hay and Alfalfa Silage Alone and with Supplements of Grain, Hay, or Corn Silage for Growing Dairy Calves. J. Dairy Sci. 42:651. 1959.

85. Thomas, J. W., J. F. Sykes, and L. A. Moore. Production and Growth of Dairy Cows Reared on Silage or Hay Rations. J. Dairy Sci. 42:1949. 1959a.

86. Trimberger, G. W. The Influence of Curing and Storage Methods on the Feeding Value of Roughages for Dairy Cattle. Paper presented to Cornell Livestock Advisory Council. 1953.

87. Trimberger, G. W., W. K. Kennedy, K. L. Turk, J. K. Loosli, J. T. Reid, and S. T. Slack. Effect of Curing Methods and Stage of Maturity Upon Feeding Value of Roughages. Part I. Same Levels of Grain. Cornell Agr. Expt. Sta. Bul. 910. 1955.

88. Voelker, H. H. and E. Bartle. Feeding Values of Alfalfa Haylage, Silage, Green Chop, Pasture, and Artificially Dried Hay. J. Dairy Sci. 43:870. 1960.

89. Watson, S. J. The Science and Practice of Conservation; Grass and Forage Crops. Vol. 1. The Fertilizer and Feeding Stuffs Journal, 16 Mark Lane E. C. 3. London. 1939.

90. Waugh, R. K., H. S. Paston, R. D. Mochrie, W. R. Murley, and H. L. Lucas. Additions of Hay to Corn Silage to Maximize Feed Intake and Milk Production. J. Dairy Sci. 38:688. 1955.

91. White, G. C. and Johnson, R. E. The Role of Succulence in the Dairy Ration and Water Consumption with Different Rations. Conn. Agr. Exp. Sta. Bul. 198. 1934.

92. Wilson, C. and E. Bartle. Alfalfa Silage Versus Alfalfa Hay for Wintering Yearly Heifers. S. D. Farm and Home Res. 5:4. 1953.

93. Wiseman, H. G. and H. M. Irvin. Determination of Organic Acids in Silage. Agricultural and Food Chemistry 5:218. 1952.

94. Wittwer, L. S., W. K. Kennedy, G. W. Trimberger, and K. L. Turk. Effects of Storage Methods Upon Nutrient Losses and Feeding Value of Ensiled Legume and Grass Forage. Cornell Agr. Expt. Sta. Bul. 931. 1958.

95. Wittwer, L. S., G. W. Trimberger, W. K. Kennedy, K. R. Allred, J. T. Reid, J. K. Loosli, and K. L. Turk. Effects of Preservations upon Red Clover and Grass Forage Ensiled Without Wilting II Feeding Value. Cornell Agr. Expt. Sta. Bul. 913. 1955.

96. Woll, F. W. and E. C. Voorhies. Trials with California Silage Crops for Dairy Cows. Calif. Agr. Expt. Sta. Bul. 282. 1917.

ROOM USE ONLY