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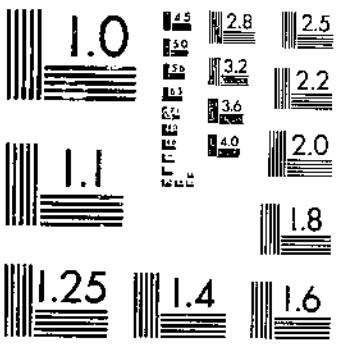

MICROCOPY RESOLUTION TEST CHART
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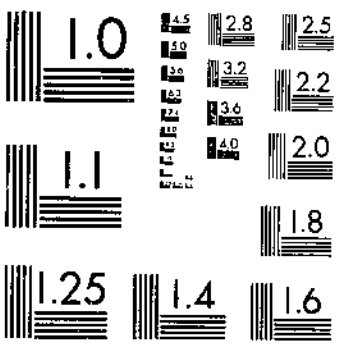

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NATIONAL BUREAU OF STANDARDS-1963-A

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METHODS OF MAKING SILAGE FROM GRASSES AND LEGUMES[1]

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CONTENTS

INTRODUCTION

In the last decade the importance of high-quality roughage for the dairy herd has come to be more generally recognized. High-quality roughage is characterized by a high degree of palatability and by generous quantities of essential food constituents.

The hays, especially, have been subjected to much careful investigation with the result that now good and poor hays are not only readily distinguishable but the reasons for the high or low quality are at least fairly well understood. Investigations in the making of silage from grasses and legumes have lagged, probably because there appeared to be little advantage in making these crops into silage when they could be made into good hay. After extensive work on hays showed that it was impossible to overcome the disastrous effects of unfavorable weather conditions at harvesting time on the nutritive qualities of field-cured hay, many investigators seriously turned to silage as the best means for saving forage crops. The fact, too, that properly made silage has been found superior to the best hay in content of carotene has stimulated interest in the making of silage.

Silage has been made successfully from hay crops in a variety of ways for many years. In the Netherlands and New Zealand stacks are used; in Finland and some of the other north-European countries

[1] Received for publication June 16, 1937.
[2] C. G. Melin, junior chemist, Division of Nutrition and Physiology, Bureau of Dairy Industry, did the analytical work.

35393°—38——1

the crops are stored in pits, sometimes with the addition of dilute acids; in the United States they have been stored to a limited extent in dirt-covered trenches and in stacks and to a greater extent in the ordinary tower silo. Efforts to make good silage from the hay crops have often been attended by failure. Undoubtedly there are certain fundamental principles which must be observed in order to make silage from such crops successfully. Just what each of these principles is has never been definitely stated in the literature.

Experiments in making silage from hay crops by various methods have been conducted recently by the Bureau of Dairy Industry at the dairy experimental farm of the National Agricultural Research Center at Beltsville, Md. Various modifications of the methods were tried in order to determine their relative efficiency in helping to preserve such crops in the silo. The experiments are described and the results presented in this bulletin, together with recommendations based on the information gained.

REVIEW OF OTHER INVESTIGATIONS

The siloing of grass and cereal crops either alone or in combination with legumes has been practiced rather extensively in some countries, and apparently is accomplished with a greater assurance of success than the siloing of legumes alone.

Legumes siloed alone have often produced ill-smelling silage, which in some cases was considered entirely unfit for feeding. The fact that legumes give the most trouble may be one reason why most of the literature on the making of silage from hay crops deals with the legumes rather than with the grasses or cereals.

A method of storing partly dried hay in silos that is said to be used considerably in Italy is described by Samarani (*25*).[3] It consists in packing hay that contains 55 to 65 percent of dry matter tightly in a silo and then weighting the top. The explanation advanced for the keeping of this silage is that the oxygen within the material is replaced with carbon dioxide in the course of 1 to 3 hours through the respiration of the living plant cells. Thereafter, if the air is effectually prevented from entering, there will be no heating and spoiling.

In a test of the Italian method of siloing hay, by Fred and Peterson, as reported by Russell and Morrison (*24*), at the Wisconsin Agricultural Experiment Station, alfalfa was dried to 60- or 70-percent dry matter, then tightly packed in a silo and heavily weighted. The silage produced was brownish green in color, had a pleasant odor, and was readily eaten by cattle. The loss of dry matter was about 5 percent.

At the Missouri station Eckles (*7*) found that partial drying of the crop before putting it in the silo was advantageous. Peas and oats with a dry-matter content of 19 percent or less made strong-smelling silage, but with dry-matter contents of 32 to 41 percent the silage was of excellent quality and readily consumed by dairy cows. Soybeans containing about 25 percent of dry matter made a bitter, unpalatable silage; those containing 30 to 40 percent made silages that were palatable and had a good odor. Cowpeas containing 12 percent of dry matter made a silage with a disagreeable odor and taste; when dried to 23-percent dry matter the odor and taste were good. Alfalfa

[3] Italic numbers in parentheses refer to Literature Cited, p. 31.

with a dry-matter content of 21 percent made a silage that was refused by dairy cows, but with dry-matter contents ranging from 42 to 63 percent it made an excellent quality of silage.

Graves and coworkers (*11, p. 12; 12, pp. 6–7*) report that 1 year two cuttings of pasture grass were placed in a silo at the Huntley, Mont., station of the Bureau of Dairy Industry. The first cutting was rather dry and mature, and for these reasons water was added at the time of filling. The resulting silage was unpalatable and apparently had undergone fermentation of an undesirable nature. The less-mature and unwatered second cutting made excellent silage. The following year (*12, p. 21*) pasture grass at different stages of maturity was successfully siloed without the addition of water or any other material.

Pasture grass as well as oats and peas have been preserved successfully in both tower silos and dirt-covered stacks by Hodgson and Knott (*15*) at the Western Washington Experiment Station.

In an experiment at the New Jersey station by Bender and others (*3*) low-moisture silage reached a high temperature and much of it spoiled.

The A. I. V. method of making silage from hay crops was developed in Finland by Virtanen (*26*). The method takes its name from the initials of its sponsor. It is based on the theory that, if the acidity of the material placed in the silo is increased so that the pH value falls below 4.0, there will be no destruction of the protein or vitamins. A mixture of concentrated hydrochloric acid and sulphuric acid diluted with five times as much water by volume is usually used to reduce the pH value. This method of siloing unchopped grasses and legumes is used successfully and to a considerable extent in some of the north-European countries.

In a test of the A. I. V. method, carried out by Peterson and others (*22*) at the Wisconsin station, silage was made from alfalfa and soybeans. The cost of acid per ton of silage ranged from 62.5 to 92.7 cents. There was no apparent loss of carotene. No unusual changes were noted in milk production due to the feeding of A. I. V. silage. Spectroscopic analyses of the butterfat for carotene and vitamin A indicated a definite increase in these components with silage feeding.

Peterson (*21*) also found that alfalfa silage made by the A. I. V. method had considerably more amino, soluble, and ammonia nitrogen than the original material. The increase, however, was less than in alfalfa siloed with nothing added. Furthermore, it had less of the volatile acids in the form of butyric acid than the untreated silage.

At the Ohio station Krauss and Washburn (*17*) and Monroe and Hayden (*18*) have done some work with A. I. V. silage. The results may be summarized as follows: First-cutting alfalfa, containing some clover and timothy, was treated with a 2 normal mixture of hydrochloric acid and sulphuric acid at the rate of 8 or 9 percent. The pH value of the silage when removed averaged 3.67. It was said to be of excellent quality and quite palatable. A comparative feeding trial indicated that A. I. V. silage might be substituted for dry hay. It was also found that the carotene content at time of storage was 130 parts per million of air-dry material, and when taken out was 219 parts per million. Hay made from the same field but wet by several rains contained about 22 parts of carotene per million parts of air-dry material.

The results of recent investigations of A. I. V. silage in England, reported by Watson and Ferguson (*28*), may be briefly stated as follows: This silage was made from grasses with an admixture of clovers. The grass at filling had a dry-matter content of 18 percent. Filling was continuous until a depth of 24 feet was reached in the silo. Fifteen gallons of a 2 normal mixture of hydrochloric acid and sulphuric acid was used per ton of grass. Filling lasted 8 days, and while this was in progress the material was weighed down at night. The silage had a pleasant odor and was eaten readily by the stock. The average pH value was 3.73. The carotene was 57.1 mg percent of dry matter.

In recent years the practice of adding molasses to the material as it is placed in the silo has increased to a marked extent in the United States. This practice is based on the theory that the production of considerable acid is necessary in the making of silage and that certain crops, notably the legumes and immature grasses, are deficient in the carbohydrates from which the acids are formed.

Probably the first attempt to make silage with the addition of molasses was reported by Reed and Fitch (*23, pp. 3–19*) at the Kansas station. Molasses was added to alfalfa at the rate of 5 to 10 percent by weight. It was said to improve both the palatability and the keeping quality of the silage. That to which 5 percent was added was more palatable than that to which 10 percent was added. The silages with molasses added had a higher acidity than those without molasses. The moisture contents for the most part were between 60 and 70 percent.

Silage of good keeping quality and possessing a characteristic but inoffensive odor was produced by this Bureau at the Huntley station (*11, p. 12; 13, p. 46*) by sprinkling diluted molasses over freshly cut alfalfa at the rate of 5 percent of the chopped alfalfa.

Bender and coworkers (*2*) in work at the New Jersey station, report excellent results on the use of molasses. Green grasses and legumes of high moisture content, with 2 percent molasses added, made a good palatable silage. The carotene in the high-moisture silage was effectively preserved. Recently, that station has been advocating as much as 3.75 percent molasses for legume silage.

In work at the South Carolina station Elting (*9*) has used molasses successfully. Soybeans in early-bloom stage with a dry-matter content of 21.25 percent were put in the silo with 1 percent of molasses and 1 percent of water. The silage kept perfectly without the development of objectionable odors. It was palatable and was consumed with little waste. A loss of 15 percent of the protein was indicated. When the silage was fed as the sole roughage to heavy milking cows, positive calcium and phosphorus balances were obtained. No objectionable flavors or odors were imparted to the milk even when the silage was fed immediately before milking.

At the Upper Peninsula substation in Michigan, Horwood and Wells (*16*) made good alfalfa silage with the addition of 3 percent of molasses. The dry-matter content of the silage was 29 percent, and the carotene content was 22 to 24 parts per million of air-dry material. A feeding experiment indicated that the silage was fully as effective as alfalfa hay for the production of milk, but less effective than the hay for increasing the body weights.

At the Ohio station Perkins (*1*) compared alfalfa silages made by partial drying and by the addition of molasses. He states that one of

the simplest, most promising, and least expensive methods consists merely in allowing the material to dry after harvesting until it has a dry-matter content of around 35 to 40 percent before it is put in the silo. The addition of molasses to such material made little or no noticeable difference in the quality of the resulting silage.

Work by Nevens and Kuhlman (*20*) at the Illinois station indicated that the addition of molasses had little or no effect on the acidity developed, but the molasses did improve the palatability of the silage. The alfalfa silage was found to be a very palatable feed for dairy cows, and when fed in limited amounts had a feeding value comparable with corn silage, but was more laxative.

The results of an experiment in England, described by Watson and Ferguson (*28*), in which molasses was used, may be summarized as follows: Herbage consisting of grasses with an admixture of clovers and containing 18 percent of dry matter was placed whole to a depth of 16 feet in a metal silo. Molasses at the rate of 0.75 percent was added after dilution with twice its volume of water. A 4½-foot layer of material was put in and allowed to heat for a day before filling was resumed. The process was repeated until 16 feet of material was put in. Temperatures rose to between 80° and 100° F. The silage was extremely good as the grass had undergone a rapid and extensive lactic fermentation—the chief point in making good silage. The average pH value of the silage was 3.95. The carotene content was 49.8 mg percent of dry matter. Another investigation by these workers in England (*29*) lead them to conclude that with grass silage no addition is necessary if the crop is cut at a fairly advanced stage of growth, but if cut while relatively immature it is better to add molasses in order to insure that the fermentation follows a suitable course. They also state that the best quality of silage is made and the losses are the lowest if acids are added according to the A. I. V. method.

Wilson and Webb (*30*) of Cornell University studied the relation of the water soluble carbohydrates in forage crops to the quality of the silage made from those crops. They showed that the crops which normally are made into good silage without trouble are crops that have a high content of water soluble carbohydrates, and suggested that sugars be added to those crops that have low quantities of water soluble carbohydrates. It appears, however, that the addition of sugar lowers the pH value by only about 0.3. A study of their data indicates that partial drying was fully as effective in improving the silage as the addition of sugar.

As a result of silage investigations conducted at the University of Wisconsin, Bohstedt (*4*) states that the system of siloing legumes with the addition of acids is more dependable and more efficient than the system involving the addition of molasses and this, in turn, is more dependable and efficient than the method of siloing without the addition of anything.

Fagan and Ashton (*10*) compared several methods of making silage from unchopped grasses in pits. They state that when the chemical composition, loss of dry matter, and palatability of the silage are taken into consideration, the molasses treatment or method appears better than the A. I. V. method or the ordinary method where nothing is added. They conclude that the ordinary method is unsuitable.

Ellenberger (*8*) has done much careful work on the siloing of the hay crops. He states:

> Our trials thus far indicate that for best results grasses and legumes should go into the silo containing approximately 65 percent water or 35 percent dry matter. Either grasses or legumes will make good silage without the addition of molasses or acids if the moisture conditions are just right, but under ordinary farm conditions it is probably a good insurance policy to add two or three percent of molasses to the green material as it goes through the cutter. This will aid in preserving the nutrients should the moisture content be a little low or a little high. Thus far we are not very favorably impressed with the acid treatment.

At the New Jersey station, Bender and coworkers (*2*) found that molasses-treated grass silage fed with hay gave slightly better results in feeding experiments than the molasses-treated grass silage alone. The principal difference appeared to be in the maintenance of body weights.

At the Wisconsin Agricultural Experiment Station, Hegsted and Bohstedt (*14*) showed that molasses-treated silage and A. I. V. silage were about the same value for maintaining weight and producing milk. Check rations containing alfalfa hay and adjusted to the same nutritive ratio and energy intake gave equally good results.

At the Ardmore, S. Dak., field station of this Bureau (*5, p. 220; 11, p. 13*), sweetclover cut when it was just coming into bloom was put in the silo with the addition of 1 ton of corn silage (made the previous year) to 20 tons of sweetclover. The resulting silage was dark green in color and had a pungent odor which lessened as the silage aged. There was practically no spoilage, and apparently the bitter taste of the sweetclover had disappeared.

The literature is replete with reports of experiments on making grass or legume silage in Europe and South Africa. Most of these investigations have to do with the effects of acids or sugar, or mixtures of both acids and sugar, on the composition and apparent quality of the silage. A considerable number of them were conducted entirely within a laboratory. It also seems likely that the material used in most cases was not chopped, because the matter of chopping is seldom mentioned. Apparently few, if any, of these investigations were conducted with silos such as are commonly used in this country. As it appeared that the results of the investigations in other countries might not be entirely applicable here, no attempt has been made to review in detail the great mass of literature available.

EXPERIMENTS WITH METHODS OF MAKING GRASS OR LEGUME SILAGE

MAKING GRASS SILAGE

An experiment in methods of making silage from hay crops was started in 1933. The principal problems in making grass silage that appeared to be in need of solution at that time were as follows: Should the grass be chopped before it is placed in the silo? What is the influence of the moisture content and of the maturity of the crop on the quality of the silage? Can grasses that ordinarily make a poor quality of hay be utilized better by placing them in the silo? What is the advantage, if any, of adding dilute acids or molasses to the material as it is placed in the silo?

The efficacy of the different methods tried in this experiment was determined by the quantity of material that could be put in a silo of given size, the extent of spoilage, the loss of nutrients, the temperatures attained, the acidity developed, and the appearance, odor, and palatability of the silage.

Wooden stave silos approximately 4 feet in diameter and 8 feet high were used for this work. In all the trials the grass to be chopped was run through a silage cutter set to cut the material in lengths one-half inch or less. The chopped grass in all cases was blown on a floor and weighed in baskets before putting it in the silo. Unchopped grass was used only in the first trial. Promptly after the silos were filled, a wooden follower was placed on top and weight applied at the rate of 40 to 45 pounds per square foot of surface. This was for the purpose of more nearly simulating the conditions in a deeper silo.

FIRST TRIAL

Orchard grass beginning to head out was used in the first trial. One silo was filled with fresh, green, unchopped grass; another with similar grass chopped; and the third with similar grass that was chopped after being partially dried.

The grass for the first two silos was cut at 10 a. m., May 11, 1933, and put in the silos at 11 a. m., May 12. After this grass was mowed there was some rain and no sunshine, so that the material as put in the two silos contained an abnormally high quantity of moisture. The third silo was filled on May 15 with grass that had been mowed 3 days earlier.

The leakage of juices from the first two silos was considerable. The unchopped silage settled over 5 feet, leaving less than 3 feet in the silo. The chopped silage settled 3½ feet and that which was partly dried less than 3 feet. Feeding started July 12, 1933, using the same two Holstein-Friesian and two grade Holstein cows for each lot of silage. The silage was fed as the sole ration. The results of this first trial are shown in table 1.

The results showed that chopping was advantageous in that more grass could be put in a given space, the quantity of spoiled silage was reduced, the edible silage had a better appearance and odor, and the cows ate greater quantities than when similar grass was stored without chopping. Partial drying increased the quantity of dry matter that could be put in a silo of given size in this experiment, increased the losses from surface spoilage, and did not lower the quality of the edible silage in appearance or palatability.

SECOND TRIAL

In the second trial, July 25–26, 1933, the herbage put in two silos was mostly second-growth orchard grass, which was 8 to 10 inches high and mixed with some white clover and lespedeza. It was allowed to dry in the field for about 4 hours after being mowed. It was then chopped and placed in the two silos. The third silo was filled with chopped Reed canary grass, which was dried to about the same extent after mowing, but was a little more mature than the orchard grass put in the other two silos. The silage was fed to four cows, of which

TABLE 1.—*Material put in silos, silage removed, silage eaten, and the quality of the silage, first to fourth trials*

Herbage used to fill 3 silos	Green grass put in silo	Dry matter in green grass		Spoiled silage taken out	Good silage taken out	Dry matter in good silage		Dry matter lost	Silage eaten per cow per day	Dry matter eaten per cow per day	Apparent quality of the silage
First trial:											
Orchard grass—	*Lb.*	*Pct.*	*Lb.*	*Lb.*	*Lb.*	*Pct.*	*Lb.*	*Pct.*	*Lb.*	*Lb.*	
Unchopped, wet	1,520	14.1	214	361	638	19.1	122	43	83	15.9	Dark, ill-smelling.
Chopped, wet	2,620	14.1	368	289	1,738	18.2	316	14	109	19.8	Good.
Chopped, partially dried.	1,210	44.3	536	147	940	42.5	399	26	55	23.4	Do.
Second trial:											
Second-cutting orchard grass, white clover, and lespedeza.	1,060	55.6	590	117	821	58.9	484	13	48	28.3	Do.
Do	1,060	55.6	606	142	897	58.9	528	13	48	28.3	Do.
Reed canary grass	930	64.3	598	201	717	60.0	430	28	36	21.6	Do.
Third trial:											
Crabgrass, pigeon grass, and alfalfa—											
61.5-percent moisture	1,340	38.5	516	126	1,080	36.0	389	25	49	17.6	Do.
62.5-percent moisture	1,407	37.5	528	123	1,165	33.0	384	27	59	19.5	Do.
32.0-percent moisture	799	68.0	537	164	542	72.0	390	27	30	21.6	Do.
Fourth trial:											
Orchard grass, white clover, and lespedeza, with—											
6 percent of acid added [1]	1,400	37.3	522	184	1,162	36.6	425	19	38	32.2	Do.
3 percent of acid added [1]	1,400	37.3	522	209	1,150	36.0	414	21	67	31.3	Do.
Nothing added	1,400	37.3	522	140	1,245	38.8	483	8	86	33.4	Do.

[1] Normal solution of hydrochloric acid.

three were from the group used in the first trial. Feeding began August 28, 1933.

The results of this second trial (table 1) confirm those of the first trial in that more dry matter can be put in a given space if the material has a low moisture content than if it has a high moisture content; also, that low-moisture silage sustains a greater surface loss. The mixture of orchard grass and legumes made a silage that was quite palatable, in this respect excelling both the Reed canary grass of this trial and the more mature orchard grass of the first trial. This trial shows that grass with a dry-matter content of above 60 percent can be siloed successfully. All the silages in the second trial appeared to have kept in perfect condition, except for the spoilage on top.

THIRD TRIAL

A spring seeding of alfalfa at Beltsville had resulted in a rather heavy growth of crabgrass and pigeon grass and only a small amount of alfalfa. Ordinarily, such herbage makes hay of poor quality because the crabgrass is difficult to cure and the pigeon grass is unpalatable. The object of this trial was to determine whether the mixture of these grasses would make a satisfactory silage. Both the crabgrass and pigeon grass had matured seeds.

The grass for two of the silos was mowed on the morning of September 11 and chopped into the silos on the afternoon of the same day. The grass for the third silo was cut on the morning of September 9 and left in the swath until the morning of September 11, when it was

raked and chopped into the silo. Feeding started October 3, 1933. Three of the four cows used were the same as were used in the second trial.

The results of the third trial are given in table 1. The silage in all three silos had a good appearance and odor, although it was not so palatable as that made in the second trial. More spoilage occurred with the drier silage, as was the case in the previous trials. In the two silos filled with grass that had a dry-matter content of about 38 percent when stored, the spoilage was limited to the top, but in the silo filled with grass that had a dry-matter content of 68 percent there was some spoilage around the sides also. The average daily consumption of silage from the first silo was smaller than of that from the second silo because one of the cows for some unknown reason did not eat the silage from the first silo readily. Although no hay made from similar material was fed in comparison with the silage, observations made in previous years indicate that the material was consumed fully as well in the form of silage as it would have been in the form of hay.

FOURTH TRIAL

The main purpose of the fourth trial was to determine the effect of additions of hydrochloric acid on the silage. Juice was expressed from a sample of the green grass intended for silage, and from the pH value of this juice it was estimated that the addition of 6 percent of a normal solution of hydrochloric acid would bring the pH to 3.5. The dilute acid was added to the chopped, green material being put in one silo at the rate of 6 percent by weight, and to that being put in another silo at the rate of 3 percent, but no acid was added to the material in the third silo. When the rate of 6 percent was desired 2.1 pounds of the dilute acid were added after each basketful of 35 pounds of grass, and when the 3-percent rate was desired 2.1 pounds of dilute acid were added after each two basketfuls of grass. Information obtained later showed that the 6-percent rate was only about half that recommended by the sponsors of the A. I. V. method, although the acidity of the silage to which 6 percent of normal acid was added was brought to a point slightly below pH 4.00.

Orchard grass about 10 inches high with some white clover and a still smaller proportion of lespedeza and crabgrass was mowed October 20, 1933, at 11:30 a. m., raked at once, and chopped into the three silos in the afternoon. A pointed half-inch pipe was driven into the top of the silage in each silo to a depth of about 30 inches. A thermometer was lowered into these pipes to obtain the temperatures. The maximum temperatures recorded were 85°, 87°, and 82° F., respectively, for the silage with 6-percent acid, 3-percent acid, and no acid added.

Only one cow, a Holstein, was used in the feeding period which began December 11, 1933. This cow consumed over 30 pounds of dry matter a day in each of the silages, which was not much less than she probably would have consumed in the green crop from which the silages were made.

The results are shown in table 1, fourth trial. The quantity of acid added appeared to have no effect one way or the other on the palatability of the silage and it did not lessen the losses of dry matter.

35393°—38——2

COMPARISON OF RESULTS FOR THE FIRST FOUR TRIALS WITH GRASS SILAGE

A few of the main facts developed in the first four trials have been mentioned. The results of these four trials, considered together, may be summarized as follows:

Wet orchard grass put in the silo without first being chopped made a silage with an offensive odor and a dark color. Much more chopped grass could be stored in a given space. At the time of filling the silos 58 pounds of unchopped orchard grass occupied the same space as 100 pounds of similar grass chopped. The losses of dry matter in the silo were three times as great for the unchopped grass as for chopped grass. The silage from the chopped grass was considerably more palatable than that from the unchopped grass, as judged by the quantities consumed by dairy cows when fed all they would eat. Furthermore, there are other reasons why the material for tower silos should be chopped. The easiest way to put a crop in the silo is to run it through a cutter and blower; and the chopped material is easier to remove from the silo than the unchopped.

Partial drying of the crop before placing it in the silo increased the quantity of dry matter that could be stored in a given space, but increased the surface spoilage. The effect of partial drying on the losses of dry matter in the silage beneath the top is discussed on page 18. Partial drying facilitated handling. This is a matter of considerable importance, in view of the unsuitability of much of the present hay-loading machinery for handling freshly mown crops. Partial drying also increased to a small extent the dry matter that would be consumed in the silage.

The maturity of the crop affects the palatability of the silage to a marked extent, just as it affects the palatability of the hay. Immature grass is more palatable than mature grass, whether it is in the green state or in the form of silage or hay. This has been well demonstrated by the Bureau at its field stations at Huntley, Mont. (*12*), and at Woodward, Okla. (*6*). The more immature the grass when harvested, however, the smaller the yield at each cutting. Experiments have shown that if frequent clipping is practiced, the total yield for the year may be reduced. It appears that there must be a compromise between the better quality of the immature crop and the larger yield and cheaper handling of the more mature crop. Probably the harvesting of grasses should never be deferred beyond the early-bloom stage.

The average quantity of dry matter consumed per cow per day when fed the different lots of silage ranged from 15.9 to 33.4 pounds. Excluding some of the silages which were not of the best quality because of being siloed without chopping or because of unpalatable grasses, the results compare very well with those obtained at Woodward (*6*), and Huntley (*12*). The dry-matter consumption of Sudan-grass silage at Woodward ranged with the different lots from 24.9 to 29.6 pounds per cow per day. That of pasture-grass silage at Huntley ranged from 20.8 to 34.4 pounds.

Grasses that make a poor quality of hay cannot be converted into the best quality of silage, but apparently they can be made into silage that will be eaten as readily as hay made from similar grasses. In general, crops that are palatable in the green state are likewise palatable when made into hay or silage; the reverse is equally true.

The losses in dry matter do not appear excessive in view of the shallowness of the silos. The subsequent work was conducted in a way that distinguished between the surface and other losses, and thus made it possible to estimate the losses that could be expected in a silo 30 or 40 feet deep.

FIFTH TRIAL

The fifth trial was not conducted until the fall of 1934. The plan for this trial differed from that of the fourth in that the dilute acid used was 2 normal instead of normal, and in that one of the silos was filled with partially dried grass. In the fourth trial only hydrochloric acid was used, but in the fifth trial sulphuric and hydrochloric acids were used in the proportions of 1 to 5 by volume. This mixture was diluted with water at the rate of 5 parts by volume of water to 1 part by volume of acid, thus making an approximate 2 normal solution.

It was thought desirable to be able to consider the losses at the top separately from those beneath the top. For this reason, a layer of building paper was placed on top of the chopped material when the silos were nearly full and then filling was completed in the usual manner. Usually the paper did not mark the exact line between the spoiled top and the rest of the silage, for there was in most cases either some silage spoiled below the paper or some unspoiled above the paper. However, it is thought that the use of the paper increased the accuracy of the work materially, although certain adjustments had to be made because of inability to place the paper at a level that would exactly separate the spoiled and the good silage. These adjustments were made on the basis that 70 pounds of spoiled silage is equivalent to 100 pounds of freshly siloed material. The average adjustment for the top portion amounted to only 2 percent of that placed above the paper. Analyses were made of the fresh material and of the good silage for moisture, nitrogen, and carotene in order that the losses of dry matter, protein, and carotene could be computed. Temperatures within the siloed material were carefully taken, and the pH value of the silages was determined.

The herbage used to fill the silos in the fifth trial was quite similar to that used the previous fall. The grass was cut on October 11, 1934, for the silo to be filled with partially dried grass. That for the other two silos was cut on October 12. All three silos were filled with the chopped grass on October 12. Feeding started March 10, 1935. A Jersey cow and a grade Holstein cow were used and neither was a very hearty eater.

The results are shown in tables 2 and 3, fifth trial. Considerably more dry matter was put in the silo when the grass was partially dried, but no doubt some of this increase was due to the extra packing at time of filling. Including the top portion the quantity of spoiled silage on a dry-matter basis was a little greater for the partially dried grass than for that in the other two silos. In this respect, the results check with those of the previous trials. The partially dried grass spoiled more on the top, but excluding the top, the three silages appear to have kept about equally well. There was no material difference in the consumption of dry matter per cow per day for the three silages.

TABLE 2.—*Material put in and taken out, dry matter lost, temperature attained, pH value of the silage, quantities of silage and dry matter eaten, and the apparent quality of the silage, fifth to tenth trials*

Trial, herbage, and treatment	Material put in silo		Acid or molasses added exclusive of top	Dry matter of material put in silo			Spoiled silage on top	Good silage taken out	Dry matter in good silage		Dry matter lost			Estimated loss of dry matter in a silo 30 feet high	Maximum temperature attained	pH value of the silage	Silage eaten per cow per day	Dry matter eaten per cow per day	Apparent quality of the silage
	Top	Exclusive of top		Percentage	Top	Exclusive of top					Top	Exclusive of top							
	Lb.	*Lb.*	*Lb.*		*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Pct.*	*Lb.*	*Lb.*	*Lb.*	*Pct.*	*Pct.*	°*F.*		*Lb.*	*Lb.*	
Fifth trial:																			
Orchard grass rowen with a little white clover and lespedeza harvested 1934:																			
Nothing added	376	1,664	0	28.5	107.2	474.2	270	1,650	28.7	473.4	107.2	0.8	0.2	4.5	68.0	4.45	59	16.7	Good.
Partially dried, nothing added	261	1,339	0	47.4	123.6	634.3	190	1,291	48.9	630.7	123.6	3.6	.6	4.3	76.0	4.77	38	18.6	Do.
6 percent of 2 normal acid added [1]	310	1,730	104	28.5	88.3	[2] 493.0	278	1,778	27.4	486.3	88.3	6.7	1.4	4.8	69.0	4.02	67	18.3	Do.
Sixth trial:																			
Second-cutting Kentucky bluegrass harvested 1935:																			
Nothing added	200	1,585	0	36.8	73.6	583.3	152	1,630	33.6	547.8	73.6	35.5	6.1	8.4	81.0	5.52	[3] 65	[3] 21.8	Do.
Partially dried, nothing added	35	1,087	0	77.8	27.3	846.6	25	1,030	79.4	817.6	27.3	29.0	3.4	4.0	93.0	5.58	[3] 29	[3] 23.0	Do.
10 percent of 2 normal acid added [1]	302	1,483	148	36.8	111.1	[2] 545.7	254	1,593	34.6	550.5	111.1	[4] 4.8	[4] .9	3.1	81.0	3.49	[3] 41	[3] 14.2	Do.
3 percent of molasses and 3 percent of water added	202	1,583	47	36.8	78.7	[5] 617.3	159	1,582	36.9	583.0	78.7	34.3	5.6	7.9	81.0	5.36	[3] 64	[3] 23.6	Do.
Seventh trial:																			
First-cutting alfalfa harvested 1934:																			
Nothing added	168	1,084	0	40.2	67.5	435.8	100	1,050	40.0	420.0	67.5	15.8	3.6	6.5	88.5	------	[6] 41.6	[6] 16.6	Do.
Partially dried, nothing added	272	582	0	60.2	163.7	350.4	188	580	59.8	346.8	163.7	3.6	1.0	9.6	91.0	------	[6] 29.5	[6] 17.6	Do.
10 percent of 2 normal acid added [1]	195	1,057	108	40.2	78.4	[2] 424.9	139	1,098	35.0	384.3	78.4	40.6	9.6	12.8	82.5	------	[6] 30.7	[6] 10.7	Do.
Made into field-cured hay	------	[7] 793	------	[7] 62.8	------	[7] 498.0	------	[8] 567	[8] 85.3	[8] 483.6	------	[9] 14.4	[9] 2.9	------	------	------	[6] 23.1	[6] 19.7	
Eighth trial:																			
First-cutting alfalfa harvested 1935:																			
Nothing added	331	1,699	0	28.3	93.5	480.0	217	1,649	25.6	422.0	93.5	58.0	12.1	15.4	96.0	5.30	54.8	[9] 14.0	Do.
10 percent of 2 normal acid added [1]	270	1,760	176	28.3	76.3	[2] 497.2	168	1,867	25.8	482.1	76.3	15.1	3.0	5.9	93.0	3.55	33.5	[9] 8.6	Do.
3 percent of molasses and 3 percent of water added	242	1,788	54	28.3	73.6	[5] 545.1	147	1,820	26.1	475.6	73.6	69.5	12.7	15.4	97.0	4.93	51.5	[9] 13.5	Do.
Field-cured hay	------	[7] 2,170	------	[7] 28.3	------	[7] 613.0	------	[8] 588	[8] 87.8	[8] 516.0	------	[10] 97.0	[10] 15.8	------	------	------	19.8	[9] 17.4	

Ninth trial:																		
First-cutting alfalfa harvested 1936:																		
Nothing added	245	1,835	0	25.5	62.6	468.8	142	1,763	24.4	429.3	62.6	39.5	8.4	10.8	80.0	5.48	72.5	17.7	Strong odor.
9 percent of 2 normal acid added [1]	232	1,848	160	25.5	59.3	[2] 472.2	138	1,801	24.1	433.2	59.3	39.0	8.3	10.5	73.0	3.66	42.7	10.3	Good.
3 percent of molasses and 3 percent of water added	173	1,907	56	25.5	47.9	[3] 528.7	107	1,918	24.8	475.7	47.9	53.0	10.0	11.6	78.0	5.13	78.1	19.4	Strong odor.
Partially dried, nothing added	216	1,104	0	75.1	162.2	829.0	177	1,093	74.0	808.7	162.2	20.3	2.4	6.1	89.0	5.20	39.7	20.4	Good.
Partially dried, 14 percent of 2 normal acid added [1]	223	1,097	158	75.9	169.1	[2] 832.1	167	1,222	63.5	775.7	169.1	56.4	6.8	10.4	89.0	3.54	29.2	18.5	Do.
Partially dried, 3 percent of molasses and 3 percent of water added	191	1,129	34	75.5	148.6	[3] 877.3	141	1,186	72.3	857.4	148.6	19.9	2.3	5.5	85.5	5.12	42.9	31.0	Do.
U. S. No. 2 alfalfa hay, fed for comparison																	[11] 24.9	22.4	
Tenth trial:																			
Soybeans, harvested 1936:																			
Cut in ¼-inch lengths, nothing added	219	1,981	0	29.6	64.7	585.6	74	1,912	29.1	556.0	64.7	29.6	5.1	7.1	97.0	5.04	76.5	22.2	Do.
Cut in ¾-inch lengths, nothing added	272	1,768	0	27.7	75.3	489.6	196	1,668	24.7	412.5	75.3	77.1	15.7	18.3	89.5	5.12	64.0	15.8	Odor, stronger than that preceding.
Cut in ¼-inch lengths, partially dried, nothing added	195	1,656	0	55.8	108.8	924.0	138	1,586	57.6	913.5	108.8	10.5	1.1	3.4	89.5	5.42	41.7	24.0	Good
Cut in ¼-inch lengths, 3 percent of molasses and 3 percent of water added	204	1,996	59	33.8	73.4	[3] 718.2	149	1,977	32.7	646.9	73.4	71.3	9.9	11.7	97.0	4.66	69.3	22.7	Do.
Chopped soybean hay, fed for comparison																	[11] 22.5	18.9	

[1] A 2 normal solution of hydrochloric and sulphuric acid.
[2] Does not include any dry matter the acid may have added.
[3] 4 pounds of grain a cow a day was fed also.
[4] Gain instead of loss.
[5] Includes the dry matter of the added molasses.
[6] 6 pounds of grain a cow a day was fed also.
[7] Represents hay when stored in mow.
[8] Represents hay when taken out of mow.
[9] 1 of 3 cows fed 6 pounds of grain a day.
[10] Includes losses in both field and mow.
[11] Dry hay.

TABLE 3.—*Dry matter, protein, and carotene put in and taken out with percentage losses, exclusive of spoiled layer on the surface*

Trial, material, and treatment	Total weight	Dry matter		Protein (N×6.25) in the dry matter		Carotene in the dry matter	
						Parts per million	*Weight in 100 pounds*
Fifth trial:							
Orchard grass rowen with a little white clover and lespedeza, harvested 1934:							
Nothing added:	*Pounds*	*Percent*	*Pounds*	*Percent*	*Pounds*		
Material put in silo	1,664	28.5	474.2	[1] 14.17	67.19	332	15.74
Silage taken out	1,650	28.3	473.4	[1] 14.55	68.88	268	12.69
Loss, percent			.2		+2.5		19.4
Partially dried, nothing added:							
Material put in silo	1,339	47.4	634.3	[1] 14.06	89.31		
Silage taken out	1,291	48.9	630.7	[1] 14.93	94.16	199	12.55
Loss, percent			.6		+5.4		
6 percent of 2 normal acid added:							
Material put in silo	1,730	28.5	[2] 493.0	[1] 14.17	69.86	332	16.37
Silage taken out	1,778	27.4	486.3	[1] 16.12	78.39	204	14.30
Loss, percent			1.4		+12.2		12.6
Sixth trial:							
Second-cutting Kentucky blue grass, harvested 1935:							
Nothing added:							
Material put in silo	1,585	36.8	583.3	[1] 14.59	85.10	268	15.63
Silage taken out	1,630	33.6	547.8	[3] 16.06	87.98	245	13.42
Loss, percent			6.1		+3.4		14.1
Partially dried, nothing added:							
Material put in silo	1,087	77.9	846.6	[1] 11.87	100.49	184	15.58
Silage taken out	1,030	79.4	817.6	[3] 12.31	100.65	146	11.94
Loss, percent			3.4		+.2		23.4
10 percent of 2 normal acid added:							
Material put in silo	1,483	36.8	[3] 545.7	[1] 14.59	79.62	268	14.62
Silage taken out	1,593	34.6	550.5	[3] 15.19	83.62	249	13.71
Loss, percent			+.9		+5.0		6.2
3 percent of molasses and 3 percent of water added:							
Material put in silo	1,583	36.8	[4] 617.3	[1] 14.59	[5] 90.49	268	16.54
Silage taken out	1,582	36.9	583.0	[3] 15.00	87.45	252	14.69
Loss, percent			5.6		3.4		11.2
Seventh trial:							
First-cutting alfalfa, harvested 1934:							
Nothing added:							
Material put in silo	1,084	40.2	435.8	[1] 14.30	62.32		
Silage taken out	1,050	40.0	420.0	[1] 12.02	53.00	31.5	1.32
Loss, percent			3.6		15.0		
Partially dried, nothing added:							
Material put in silo	582	60.2	350.4	[1] 13.92	48.78		
Silage taken out	550	59.8	346.8	[1] 14.33	49.70	41.8	1.45
Loss, percent			1.0		+1.9		
10 percent of 2 normal acid added:							
Material put in silo	1,057	40.2	[2] 424.9	[1] 14.30	60.76		
Silage taken out	1,008	35.0	384.3	[1] 14.88	57.18	112.0	4.30
Loss, percent			9.6		5.9		
Made into field-cured hay:							
Hay put in the mow	703	62.8	498.0	15.29	76.14		
Hay taken out of the mow	567	85.3	483.6	13.27	64.17	24.6	1.19
Loss, percent			2.9		15.7		
Eighth trial:							
First-cutting alfalfa, harvested 1935:							
Nothing added:							
Material put in silo	1,699	28.3	480.0	[1] 16.82	80.74	164.2	7.88
Silage taken out	1,649	25.6	422.0	[1] 15.25	64.35	175.4	7.40
Loss, percent			12.1		20.3		6.1
10 percent of 2 normal acid added:							
Material put in silo	1,760	28.3	[2] 497.2	[1] 16.82	83.63	164.2	8.16
Silage taken out	1,867	25.8	482.1	[1] 17.69	85.28	167.8	8.09
Loss, percent			3.0		+2.0		.9
3 percent of molasses and 3 percent of water added:							
Material put in silo	1,788	28.3	[4] 545.1	[1] 16.82	[5] 92.17	164.2	8.95
Silage taken out	1,820	26.1	475.6	[1] 15.53	73.86	112.0	5.33
Loss, percent			12.7		19.9		40.4
Made into field-cured hay:							
Freshly mown hay	2,170	28.2	613.0	[1] 16.82	103.11	164.2	10.07
Cured hay	588	87.8	516.0	[1] 16.56	85.45	16.2	.84
Loss, percent			16.8		17.1		9.2

See footnotes at end of table.

TABLE 3.—*Dry matter, protein, and carotene put in and taken out with percentage losses, exclusive of spoiled layer on the surface*—Continued

Trial, material, and treatment	Total weight	Dry matter		Protein (N×6.25) in the dry matter		Carotene in the dry matter	
						Parts per million	*Weight in ¼₀₀ pounds*
Ninth trial:							
First-cutting alfalfa, harvested 1936:							
Nothing added:	*Pounds*	*Percent*	*Pounds*	*Percent*	*Pounds*		
Material put in silo	1,835	25.6	468.8	[1] 19.55	91.65	174.2	8.17
Silage taken out	1,763	24.4	429.3	[2] 21.50	92.30	207.7	8.92
Loss, percent			8.4		+.8		+9.2
9 percent of 2 normal acid added:							
Material put in silo	1,848	25.6	[3] 472.2	[1] 19.55	92.32	174.2	8.23
Silage taken out	1,801	24.1	433.2	[2] 19.11	82.78	218.2	9.45
Loss, percent			8.3		10.3		+14.8
3 percent of molasses and 3 percent of water added:							
Material put in silo	1,907	25.6	[4] 528.7	[1] 19.55	[5] 103.86	174.2	9.21
Silage taken out	1,918	24.8	475.7	[2] 20.00	95.14	152.9	7.27
Loss, percent			10.0		8.4		21.1
Partially dried, nothing added:							
Material put in silo	1,104	75.1	829.0	[2] 17.50	145.07	100.9	8.36
Silage taken out	1,093	74.0	808.7	[2] 15.87	128.34	49.5	4.00
Loss, percent			2.4		11.5		52.2
Partially dried, 14 percent of 2 normal acid added:							
Material put in silo	1,097	75.9	[3] 832.1	[2] 17.50	145.62	100.9	8.40
Silage taken out	1,222	63.5	776.7	[2] 18.81	145.91	63.5	4.93
Loss, percent			6.8		+.2		41.3
Partially dried, 3 percent of molasses and 3 percent of water added:							
Material put in silo	1,129	75.5	[4] 877.3	[2] 17.50	[5] 153.83	100.9	8.85
Silage taken out	1,186	72.3	857.4	[2] 16.87	144.64	50.5	4.33
Loss, percent			2.3		6.0		51.1
Tenth trial:							
Soybeans, harvested 1936:							
Cut in ¾-inch lengths, nothing added:							
Material put in silo	1,981	29.6	585.6	[3] 14.28	83.62	100.9	5.91
Silage taken out	1,912	29.1	556.0	[2] 15.58	86.62	67.0	3.73
Loss, percent			5.1		+3.6		36.9
Cut in ¾-inch lengths, nothing added:							
Material put in silo	1,708	27.7	489.6	[3] 13.80	68.05	110.1	5.39
Silage taken out	1,608	24.7	412.5	[2] 15.87	65.46	82.9	3.42
Loss, percent			15.7		3.8		36.5
Cut in ¼-inch lengths, partially dried, nothing added:							
Material put in silo	1,656	55.8	924.0	[3] 12.63	116.70	45.8	4.23
Silage taken out	1,586	57.6	913.5	[2] 13.25	121.04	20.2	1.85
Loss, percent			1.1		+3.7		56.3
Cut in ¼-inch lengths, 3 percent of molasses and 3 percent of water added:							
Material put in silo	1,996	33.8	[4] 718.2	[3] 14.66	[5] 105.82	91.7	6.59
Silage taken out	1,977	32.7	646.9	[2] 14.56	94.19	62.4	4.04
Loss, percent			9.9		11.0		38.7

[1] Analyses for nitrogen made of air-dry material.
[2] Does not include any dry matter the acid may have added.
[3] Analyses for nitrogen made of moist material.
[4] Includes dry matter of the added molasses.
[5] Includes protein of the added molasses.

SIXTH TRIAL

The silos for the sixth trial were filled in the fall of 1935. Kentucky bluegrass which had grown up after the removal of a crop of hay in the summer was used. Three silos were filled in the afternoon of October 8 with grass that was mowed and loaded on trucks in the morning of the same day. Another silo was filled with similar grass on October 11. The grass for this silo was mowed on October 10 and lay in the swath for about 26 hours when it was raked and hauled to the silo.

This trial differed from the fifth in that molasses was added to the contents of one silo, 10 percent of acid instead of 6 percent was added to another silo, and that which was partially dried was dry enough so

that it could have been put in the mow or stack. The silage was fed to three cows beginning January 1, 1936. The results are given in tables 2 and 3, sixth trial.

The quantity of spoiled silage on top was greatest in the silo to which acid was added and least in the one filled with partially dried grass. The percentage loss of dry matter, including that in the spoiled top, was least for the dry silage and about the same for the other three, if allowance is made for the dry matter in the added molasses and none is made for any dry matter the acid may have added. All of the silages appeared to be good, but that to which acid was added was distinctly less palatable than the others. There was no material difference in the palatability of the other three.

MAKING LEGUME SILAGE

It appeared that the principal problems in the making of legume silage concerned the matter of partially drying the mowed crop before placing it in the silo, and either the use of dilute acids or the addition of molasses. Several series of experiments were planned for the purpose of determining the practicability of these different treatments. In every series one silo was used as a control. The material was always chopped fine, one-half inch or less; it was weighed into the silos accurately in baskets and weighed out in a similar manner; the top was always covered and weighted with a load of 40 to 50 pounds per square foot the same day the silo was filled. In applying the acid or molasses the uniform practice was to sprinkle a measured quantity of the acid or molasses over the chopped material after every two basketfuls (30 to 40 pounds to the basket) were placed in the silo.

SEVENTH TRIAL

There were two main objects of the seventh trial; one was to determine the best methods of making silage from legumes, and the second to learn whether a crop is better utilized when made into hay than when made into silage.

First-cutting alfalfa was mowed June 13, 1934, and raked at once with a side-delivery rake. Each windrow was then divided into successive lengths of 20, 10, and 10 feet, with the expectation that there would be twice as much in the 20-foot lengths as in either of the 10-foot lengths and that there would be the same quantity in each of the 10-foot lengths. The sections 20 feet long were hauled in at once, run through a cutter, and the total amount equally divided between two silos. Nothing was added to the contents of one silo; 10 percent of 2 normal acid was added to the contents of the other.

The following day, June 14, one series of 10-foot sections was chopped and run into a small silo. The dry matter of this lot was 60.2 percent as compared with 40.2 percent in that put in the previous day. After this silo was filled, and on the same day, the remaining series of 10-foot sections was placed in the hayloft. The percentage of dry matter of this lot was 62.8. If any considerable quantity of hay as moist as this is stored it will heat. The reason this did not heat is explained by the small quantity and by the fact that it was left as loose as possible to facilitate drying. Feeding of the silage started July 14, three cows being used. The results of this trial are shown in tables 2 and 3, seventh trial.

EIGHTH TRIAL

The objects of the eighth trial were much the same as those of the previous trial, but the procedure with the silage was different in that one silo was filled with alfalfa to which molasses was added, whereas it had been filled with partially dried alfalfa in the previous trial. A further difference was that the windrows in the seventh trial were divided into successive measured lengths in order to get the same quantity in each of the silos as was made into hay, whereas in the eighth trial the green material was collected as soon as possible after being mowed and that intended for silage was chopped and that intended for hay was weighed and spread in a windrow in the field to dry.

First-cutting alfalfa was mowed in the morning of June 5, 1935, and loaded on three trucks at once. Loading was finished at 11:15 a. m. The three loads amounted to over 8,000 pounds, of which 6,090 pounds was chopped and put in three silos. Chopping was finished at 1 p. m., and filling at 3:45 p. m. The remainder was used for hay and was spread from the truck in windrows at 3:30 p. m. There was a rain on the night of June 5. The windrows were opened up at noon June 6, turned at noon June 7, loaded on a wagon at 4 p. m. June 7, and put in the hayloft at 9 a. m. on June 8. The weight of the green alfalfa before it was spread out in windrows was 2,170 pounds. When it was placed in the loft the weight was 1,030 pounds, from which it is estimated that the dry-matter content was about 60 percent. Feeding of the silages started July 31, using three cows. The results of feeding the silages and the hay are shown in tables 2 and 3, eighth trial.

It will be noted in the results for the seventh trial that the loss of dry matter in the hay from the time it was put in the loft until fed was only 2.9 percent, which was somewhat less than the loss in any of the silages. In the eighth trial the dry-matter loss in the hay, from the green state to the dry state at time of feeding, was 15.8 percent, which was a little more than the loss from any of the silos. No doubt the rain on the hay that was used in the eighth trial had much to do with the large dry-matter loss of this hay as compared with that of the seventh trial, but it should also be observed that the loss in the eighth trial is the total from the time of mowing, while that in the seventh trial is only that occurring in the loft.

NINTH TRIAL

In the ninth trial six small silos were filled with first-cutting alfalfa. Fresh green alfalfa containing 25.6 percent of dry matter was put in three of them, and dried alfalfa containing 75 or 76 percent of dry matter was put in the other three. To one silo of each group, acid was added; to another, molasses was added; and to the third, which was used as a check, nothing was added.

The alfalfa for three of the silos was mowed on the morning of May 26, 1936, and hauled in at once. Filling was completed at 1:30 p. m. on May 26. The alfalfa for the other three silos was mowed May 23, raked on the morning of May 25, chopped at 9:30 a. m., and filling was completed at 2:30 p. m. of the same day.

Palatability tests of the silages were conducted with four cows beginning August 2, 1936. At the conclusion of these silage tests the same four cows were fed all they would eat of U. S. No. 2 alfalfa hay. The average daily consumption of hay was 24.9 pounds, con-

taining 22.4 pounds of dry matter. This was somewhat less dry matter than was consumed in the silage from partially dried alfalfa that was not treated with molasses or in that treated with molasses, but more than was consumed in the silage from the fresh green alfalfa. The results of this work are shown in tables 2 and 3, ninth trial.

TENTH TRIAL

Soybeans were placed in four silos as follows: (1) Material used for check, chopped with cutter set for ¼-inch lengths; (2) similar material, except that cutter was set for ¾-inch lengths; (3) partially dried material, with the cutter set for ¼-inch lengths; and (4) same as check except molasses was added. Freshly-cut soybeans were used for three of the silos, and some that had been cocked for haymaking were used for the one filled with partially dried material. Filling was done on September 17, 1936, and feeding began on November 6. The results are given in tables 2 and 3, tenth trial.

The silage cut in ¾-inch lengths sustained a marked loss in dry matter and was not as palatable as the other silages. Whether further investigations would confirm this result remains to be determined. The other silages behaved much as would have been expected from the previous trials. In comparative feeding tests, a good grade of chopped soybean hay was not eaten in as large quantities (on a dry-matter basis) as the silages chopped into ¼-inch lengths.

INFLUENCE OF METHODS ON RESULTS OBTAINED WITH THE SMALL SILOS

The results of the first to fourth trials have been discussed on pages 7 to 11.

The more important results obtained with grass crops in the fifth and sixth trials, and with legumes in the sixth to tenth trials, inclusive, shown in tables 2 and 3, are brought together in table 4. This comparison illustrates the average results obtained by partially drying the green material before placing in the silo, or by adding acid or molasses, as compared with using fresh green material with nothing added.

PARTIAL DRYING

In the trials given in table 4 the silages made from grass or legumes partially dried to a low moisture content sustained a greater surface loss than those high in moisture if the spoilage on top is included. If the spoilage on top is not included, the loss of dry matter was lower in the low-moisture silage than in the high-moisture silage. The low-moisture materials not only contained less carotene than the high-moisture materials at the time they were placed in the silo, but the percentage loss of carotene in the silo was also greater. The low-moisture silages became 3° or 4° warmer on an average than the high-moisture silages, but none of the silages at any time reached a temperature above 97° F. The pH value of the untreated silages as a rule ran above 5. If the grass or legume silage was low in moisture content, the quality of the silage, as judged from the appearance and odor, was invariably good but if the silage was a legume with a high moisture content and was not treated with acid it might have a strong odor. In every instance the average dry-matter consumption

by the cows was greater when fed low-moisture silage than when fed high-moisture silage. When alfalfa hay was fed for comparison with alfalfa silage, in one out of three instances they ate more dry matter in hay than in low-moisture silage, and in two out of three instances they ate more dry matter in hay than in high-moisture silage.

TABLE 4.—*Average losses sustained, palatability, temperatures and pH value of silages partially dried or treated with either acid or molasses, trials 5 to 10*

Treatment	Silages compared	Losses exclusive of top			Estimated loss of dry matter in a silo 30 feet high	Dry matter eaten per cow per day	Temperatures attained	pH value of the silage
		Dry matter	Protein	Carotene				
	Number	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*°F.*	
Green or partially dried:								
Green	5	4.7	0.9	[1] 13.9	7.5	19.0	82.9	[2] 5.12
Partially dried	5	1.7	+.1	[1] 44.0	5.5	22.5	87.7	[2] 5.24
Green, with or without acid:[3]								
Nothing added	6	5.5	6.7	[4] 16.5	8.6	19.4	83.7	[4] 5.19
Acid added	6	4.7	+.5	[4] 9.2	7.9	13.4	81.2	[4] 3.65
Green, with or without molasses:[3]								
Nothing added	5	6.8	4.8	20.0	9.6	21.0	88.6	5.31
Molasses added	5	8.1	9.7	32.5	10.4	22.6	87.7	5.04
Green with acid or molasses:								
Acid added	4	4.3	.8	8.4	7.5	12.9	84.0	3.56
Molasses added	4	7.6	9.4	30.9	10.1	21.9	85.4	5.12
Green with acid or partially dried:								
Acid added	4	4.6	+.2	[5] +4.3	7.8	13.4	76.4	[1] 3.72
Partially dried	4	1.8	1.0	[5] 37.8	6.0	22.1	87.2	[1] 5.18
Green with molasses or partially dried:								
Molasses added	3	8.5	7.6	23.7	10.4	21.9	85.3	5.05
Partially dried	3	2.3	2.5	44.0	4.5	25.5	90.5	5.40

[1] 3 comparisons.
[2] 4 comparisons.
[3] Includes 1 comparison in which partially dried material was used.
[4] 5 comparisons.
[5] 2 comparisons.

EFFECT OF ADDING ACID

The addition of acid reduced slightly the loss of dry matter, when any dry matter the acid itself may have added is disregarded, and it reduced slightly the loss of carotene. The temperatures of the acid-treated silage were 2° or 3° lower on the average than those of the untreated silage, a difference explainable wholly or in part by the higher moisture content of the acid-treated silage. The pH value was well below 4 except in one instance when it was 4.02. The acid-treated silage was distinctly less palatable than the untreated silage, except for silage with a pH value of 4.02. Two hundred grams of finely ground limestone were sprinkled over the daily ration of each cow fed acid-treated silage.

Treatment with acid had very little influence on the loss of nitrogen when the analyses were made of the moist silages. But when the analyses were made of the silages after they had been dried the acid-treated silages showed less loss. For example, the average protein (N×6.25) content of several of the moist, check silages was 18.24 percent when calculated to a dry basis, and the protein content of these same silages when dried and then analyzed for nitrogen was 15.45 percent. Similar figures for comparable acid-treated silages were 18.58 and 18.26, respectively. In other words the check silage lost considerable nitrogen in drying; the acid-treated silage lost but very little. The molasses-treated silage had 17.40 percent protein

(dry basis) when analyzed in a moist condition and 15.87 percent when analyzed in a dry condition. The analyses also point to the conclusion that the drier the untreated silage is the smaller is the loss of nitrogen through drying. This may be a matter of some significance to anyone who is attempting to determine the nutritive value of the nitrogen compounds in silage. It is highly probable that the protein (N×6.25) of the acid-treated silage is superior in quality to that of the untreated silage, especially if the latter has a high content of moisture. Peterson (*21*) found that untreated silage with a high water content had a larger amount of amino, water-soluble, and ammonia nitrogen than A. I. V. silage.

No attempt was made in this investigation to determine the relative nutritive values of the protein in the various silages, but some comparative biological values of the proteins in silage made from summer pasture grass at the Hannah Dairy Research Institute (*19*) at Kirkhill, Ayr, Scotland, are informative. With the biological value of the protein in blood meal set at 75, the following relative values were assigned to the proteins of different silages: A. I. V. silage, 78.5; molasses silage, 75.0; and ordinary silage, 77.0. The moisture content of the silages was not stated. It would appear from the results in table 4 that in some cases more protein was contained in the silage than was present in the original material. It is unlikely that the actual quantity of protein increased. Any seeming increase can best be explained by the method of making the nitrogen determination or by errors in sampling.

EFFECT OF ADDING MOLASSES

The addition of 3 percent of molasses diluted with an equal weight of water was not advantageous so far as lessening the losses of dry matter, protein, and carotene was concerned. In making these calculations the dry matter and protein of the added molasses were included, using the average analysis of 74.1 percent dry matter and 2.8 percent protein. The temperature of the molasses-treated silages was only slightly less than that of those not treated. Perhaps the difference is no more than could reasonably be explained by the higher moisture content of the molasses-treated silage caused by the addition of diluted molasses. The pH value of the molasses-treated silage was consistently lower than that of the untreated, although the average difference was only 0.27. Possibly this small difference is sufficient to affect noticeably the appearance and odor of the silages, although no such conclusion can be drawn from the results of this investigation. It has been apparent, however, in certain laboratory specimens that the addition of molasses did improve the odor of high-moisture silages. Molasses makes the silages slightly more palatable. So far as the results of this work are concerned, this is the only advantage that can be claimed for the molasses treatment.

LOSSES OF DRY MATTER

The losses of dry matter for the most part were quite moderate. The unavoidable surface losses of dry matter for the last 23 silos filled, as shown in table 2, ranged from 27 to 169 pounds, the greater losses occurring with the drier material. If it is assumed that the extent of surface spoilage is directly proportional to the surface exposed, then the loss of dry matter on the top of a silo 14 feet in diameter would be

12.25 times that on top of a silo 4 feet in diameter and would range from 331 to 2,070 pounds. The higher figure would compare very well with the losses normally occurring in silos filled with corn, but the lower figure would be much below that which could be attained with any kind of crop, silo, or treatment without employing some special means to protect the top. In this connection it must be borne in mind that the silage in these experiments was always covered with a layer of building paper upon which was placed a wooden follower and the material for weighting the silage. Weighting appears to be desirable for all kinds of grass or legume silage, especially if the crop does not have a high content of moisture.

The dry-matter losses of the silage beneath the spoiled top ranged from practically nothing to 15.7 percent. The greater losses occurred in the wetter silages, but the greatest loss was with soybeans which not only had a high content of moisture but were also cut in long lengths. The average percentage of dry matter lost in the edible silage of the last 23 silos was 5.6.

If the losses of dry matter both in the spoiled surface and in the unspoiled silage underneath are taken into consideration, and if it is assumed that the surface losses are directly proportional to the surface area and also that the percentage losses of the unspoiled silage would be the same for deeper silos, one can estimate the losses in silos of greater diameter and having a column of silage say five times the depth of the silages used in these experiments. Estimations made on this basis show that the losses of dry matter ranged from 3 to 18 percent, with an average loss of 8.6 percent. As a rule, the high-moisture silages were estimated to sustain greater losses than the low-moisture silages. The larger surface losses of the drier silages were more than counterbalanced by the losses of dry matter in the edible portion of the wetter silage.

Watson (*27*) has reported dry matter losses of 18.2, 16.1, and 17.7 percent in ordinary silage, molasses-treated silage, and A. I. V. silage, respectively. Probably the reason these losses are higher than those reported in this investigation is that Watson's material was not chopped. More air is enclosed with unchopped material and a greater oxidation is possible.

Hodgson and Knott (*15*) estimated the loss of dry matter (exclusive of that in the spoiled silage) to be 24.8 percent in a tower silo they were comparing with a dirt-covered stack. The high loss in the tower silo can be attributed to the absence of weighting material on top and to the admission of air through the silo walls.

The comparative losses of dry matter in silage, shown in tables 2 and 3 and summarized in table 4, as compared with the losses in hay cannot be considered conclusive for making such crops into silage as compared with making them into hay. They indicate, however, that properly made silage may sustain less loss of dry matter than hay that has been damaged by the weather, but possibly not less than hay cured quickly and without weather damage.

CAROTENE CONTENT

An outstanding characteristic of the silages as compared with the hays is their superior content of carotene. When a fresh, green, untreated crop was put in the silo the carotene content was high at the

time of filling and was preserved to a highly satisfactory degree. The addition of the acid improved the preservation of carotene; the addition of molasses did not. Both the carotene content of a crop at the time of placing it in a silo and the efficacy of carotene preservation varied inversely with the extent of drying, but even so the material dried to a low moisture content contained as much carotene as well-cured hay after a period of storage.

EXPERIMENTS WITH UNCHOPPED ALFALFA SILAGE

A few small tests were made to gain some information on whether it would be practicable for a farmer with a small number of cows and possessing neither a silage cutter nor a silo to put unchopped, green alfalfa in stacks or pits for winter use.

First-cutting alfalfa was used. It was cut in the full-bloom stage, raked immediately and all loaded on the wagons within 2 hours after being cut. At the time the alfalfa was placed in the stack and pits, the dry-matter content was 38 percent and the carotene content of the dry matter 160 parts per million.

The alfalfa was tramped firmly into a pit 4 feet deep and 8 feet in diameter and the filling continued until the alfalfa was 3½ feet above the ground level. A thin layer of straw was then placed on top and this was followed by about 1 foot of soil. Similar alfalfa was put in a pit 4 feet deep and 4 feet in diameter. Filling was continued until the alfalfa was 2 feet above the ground level, then about 1 foot of soil placed on top. The purpose of using this second pit was to determine the extent to which surface water draining into the pit would damage siloed material. Two weeks after the pit was filled 40 gallons of water were run into it, then 2 weeks later, 40 gallons, and 4 weeks later, 60 gallons.

Some of the same lot of first-cutting alfalfa was packed in a stack 7¾ feet high and 8 feet in diameter surrounded by two circles of 4-foot snow fence. This snow fence was not lined with paper or other material to exclude the air. About 1 foot of soil was placed on top as soon as the filling was completed.

The alfalfa was put in the pits and stacks on June 8, 1936. Half-inch pipes were driven into the tops of the silages and temperatures taken, beginning the next day after filling.

About 4 weeks later a small amount of partially cured, second-cutting alfalfa was pressed into a tight bale and then buried on end so that the top was about 6 or 8 inches below the surface of the ground.

The first or largest pit was opened September 3. The silage in this pit had settled to 18 inches below the surface of the ground. The silage was spoiled about 3 inches deep on top and 15 inches thick around the outer edge. Near the top the silage had the color and odor of normal alfalfa silage. As removal progressed, the moisture content increased and the silage became stronger in odor. The last foot of silage was waterlogged and had an offensive, clinging odor. The higher content of water and the greater weight of the silage as compared with the original material shows that some surface water drained into the pit. The silage was fed to six cows.

Similar conditions were found in the smaller pit, except that more of the silage was waterlogged and for that reason had an offensive odor that soap and water would not remove from the hands. This was fed to two cows.

Only 80 pounds suitable for feeding were found in the stack, and this was near the center. The remainder was quite moldy.

The top third of the bale was mostly spoiled, but the bottom half from which the air had been more effectually excluded was in good condition.

The more important observations made on these four lots of silage are given in table 5.

TABLE 5.—*Material used and results obtained for fresh, green alfalfa buried in pits below the ground, and in a stack above ground*

Material stored in—	Amount put in	Amount taken out		Dry matter in silage	Carotene, of dry matter	pH value of the silage	Maximum temperature attained	Silage eaten per cow per day	Apparent quality of the silage
		Spoiled	Good						
	Pounds	*Pounds*	*Pounds*	*Percent*	*Parts per million*		° *F.*	*Pounds*	
Larger pit	3,536	457	4,171	27.0	84	5.19	160.5	56	Top, fair, bottom bad.
Smaller pit	807	219	605	19.5	83	5.06	109.5	68	Do.
Stack	3,456	(1)	80				151.0		Spoiled.
Bale	177	40	139	65.0	61		102.0		Top moldy, bottom fair.

[1] Not weighed.

The general conclusion to be drawn from this work is that any method of siloing alfalfa whether in pits, stacks, or silos, which does not force out the air promptly from the material intended for silage and does not thereafter effectually exclude the air, as well as the drainage or seepage water, will fail. On the other hand, this work shows the possibility of making silage from unchopped alfalfa that will grade at least fair in quality. No doubt if greater attention is given to the matter of packing tightly or applying pressure, if the air is excluded by a thicker or more impervious coating of soil, if water is kept out, and if the moisture content of the crop is not too high, a good grade of silage can be made from unchopped, untreated alfalfa.

STORING GRASS AND ALFALFA IN LARGER SILOS

A monolithic concrete silo 14 feet in diameter was filled to a depth of 20 feet with chopped Kentucky bluegrass in May 1934. The dry-matter content of the grass when put in the silo was 60 percent for that at the bottom of the silo, 30 percent for that at the middle, and 40 to 45 percent for that at the top. The grass was raked with dump rakes and then taken from the windrow with a hay loader. It was neither tall enough nor thick enough on the ground for picking up cleanly with the loader from either the swath or windrow. No one was kept in the silo regularly, but the chopped grass was leveled off two or three times during the filling and once when filling was completed. When the silo was opened in November the spoilage around the outside at the top and down the sides was found to be excessive.

In 1934 another similar silo was filled to about the same height with a weedy growth of first-cutting alfalfa. The alfalfa was taken from the swath with a hay loader, chopped, and put in the silo. The dry-matter content ranged from 28 to 56 percent, the material with the lowest percentage being at the top. Aside from this layer on top,

the dry-matter content gradually decreased from top to bottom, the highest being immediately below the top and the lowest (32 percent) being near the bottom. As one of the objects of the experiment was to determine the practicability of putting alfalfa in the silo at various stages of dryness, no attempt was made to keep the dry-matter content near any certain point, although some of the heaviest material was put on top to act as a weight and seal. No one was kept in the silo regularly during filling, the material being partially leveled at intervals when the cutter was not running. The silo was opened the latter part of November, and, as in the silo containing grass, the spoilage on top and down the sides was excessive. The spoiled silage on top in the center was 2 or 2½ feet deep. Around the sides at the top it was much thicker. The silage near the top was brown in color, which indicated the presence of air and lack of sufficient packing. As removal of the silage progressed, the color improved until near the bottom it was dark green. The odor of the silage at the top was slightly penetrating, though inoffensive. The odor improved as the silage was removed.

In the spring of 1936 the same silo was filled to a depth of about 26 or 28 feet with the growth from an alfalfa field which had been taken almost completely by various grasses mixed with considerable weeds. From this field, 15,000 pounds of alfalfa hay containing only a small quantity of grasses or weeds was selected, chopped finely, and run in the bottom of the silo. This material had 81.5 percent of dry matter and was as dry as hay generally is when put in the mow or stack. The material placed on top of this alfalfa was mostly grass and for the most part contained 50 to 55 percent of dry matter. Filling was done on May 26 to 29, and the silo was opened on July 10.

The spoiled silage removed from the top and from around the sides weighed 4,070 pounds, an amount which seemed high in view of the short period since the silo had been filled. The spoilage was much greater on one side than on the other. This can be explained by the fact that the chopped grass falling at one side caused the material to be packed more solidly on that side than the other; the silage in settling leaned toward the side packed the least, thus opening up spaces that admitted air. No doubt with a longer period of storage the loss would have been much greater.

FEEDING VALUE OF THE GRASS AND LEGUME SILAGES

Feeding the grass and legume silages produced in the various trials with the small silos showed that good grass and legume silage is readily eaten by dairy cows. Although the small quantities fed did not permit significant observations of the effect on milk flow and body weight in comparison with hay, consumption compared favorably with hay in amounts eaten and dry matter consumed.

All of the edible silage in the large silos was quite palatable. It was observed that the grass silage made in the upper part of the silo in 1936 was consumed in preference to good alfalfa hay when the cattle had a free choice of either in a feed bunk. The low-moisture silage in the bottom of the silo reached a maximum temperature of 104° F., and kept perfectly without any spoilage whatever; furthermore, it had a carotene content of 38 parts per million of dry matter, or more than would be expected if the alfalfa had been stored in the barn or stack

instead of in the silo. The pH value of this material was 5.16, which is evidence that the quantity of acid formed was quite small. No detailed feeding trials were made with the contents of this silo, but the grass and legumes silages made in the large silos in 1934 were used in feeding trials lasting 14 weeks to determine their feeding values.

The grass silage made in 1934 (p. 23) was in a silo at the abortion-positive farm. Suitable cows were no longer available for a feeding trial, however, because the number of positive cows had been greatly reduced preparatory to discontinuing this isolation unit. Consequently, the silage was fed, as the sole ration, to six Jersey cows, four of which were dry or nearly so, for 8 weeks. The average consumption of dry matter by the six cows by weekly periods ranged from 15 to 23 pounds per cow per day. The feeding of grass silage was followed by a sole ration of good alfalfa hay for 4 weeks. The consumption of dry matter before and after the change was practically the same, which indicates that the grass silage was as palatable as good alfalfa hay. The loss in body weight for the 8 weeks on grass silage averaged 5 pounds per cow; for the 4 weeks on alfalfa hay the average loss was 11 pounds. Only two cows went through the feeding trial without either going dry or calving. These two cows declined 13 percent in milk production for the 8-week period on grass silage and increased 2 percent during the 4-week period on alfalfa hay. These observations are in line with the feeding experiments on silage and hay from pasture grass at Huntley (*12, p. 45*) and silage and hay from Sudan grass at Woodward (*6, pp. 27–28*).

For the alfalfa-silage feeding experiment, 12 cows were divided into 3 groups of 4 cows each. Each group consisted of three Holsteins and one Jersey. One group was fed the usual ration of alfalfa hay, corn silage, and grain; another group was fed alfalfa silage, corn silage, and grain; the third group was fed a sole ration of alfalfa silage. This made it possible to compare alfalfa silage with alfalfa hay in a ration with corn silage and grain as well as to determine the effect of alfalfa silage as a sole ration.

All three groups were fed the alfalfa silage and alfalfa hay in as large amounts as the cows would eat. The first two groups were fed corn silage at the rate of 3 pounds a day for each 100 pounds of body weight and grain enough to bring the total digestible nutrients up to the Haecker standard. Adjustments were made weekly. After 10 weeks (fig. 1) alfalfa hay was substituted for the alfalfa silage for a period of 4 weeks, in the rations of the two groups that had been receiving alfalfa silage. The group receiving no alfalfa silage in the first 10 weeks was continued on the same ration for another 4 weeks.

The average daily milk production at the start was about 30 pounds per cow, but because all the cows had been fed a ration of alfalfa silage alone for a preliminary period of several days, the milk production declined sharply. This decline accounts for the relatively small quantity of milk produced in this experiment. The average milk production of the different groups by weeks is shown in figure 1, also the average consumption of dry matter for the alfalfa hay and alfalfa silage, and the average body weights.

These curves show that the milk flow was as well maintained on a mixed ration including alfalfa silage as on one including alfalfa hay; also, that the milk flow on a ration of alfalfa silage alone was better maintained than on a mixed ration, although possibly the lower level

of production at the beginning may have had much to do with this result. It can be said in favor of the alfalfa hay that changes from alfalfa silage to alfalfa hay retarded the declines in milk production for the last 4 weeks. In the meantime the group being fed alfalfa hay, corn silage, and grain without change continued to decline at a uniform rate through the last 4 weeks.

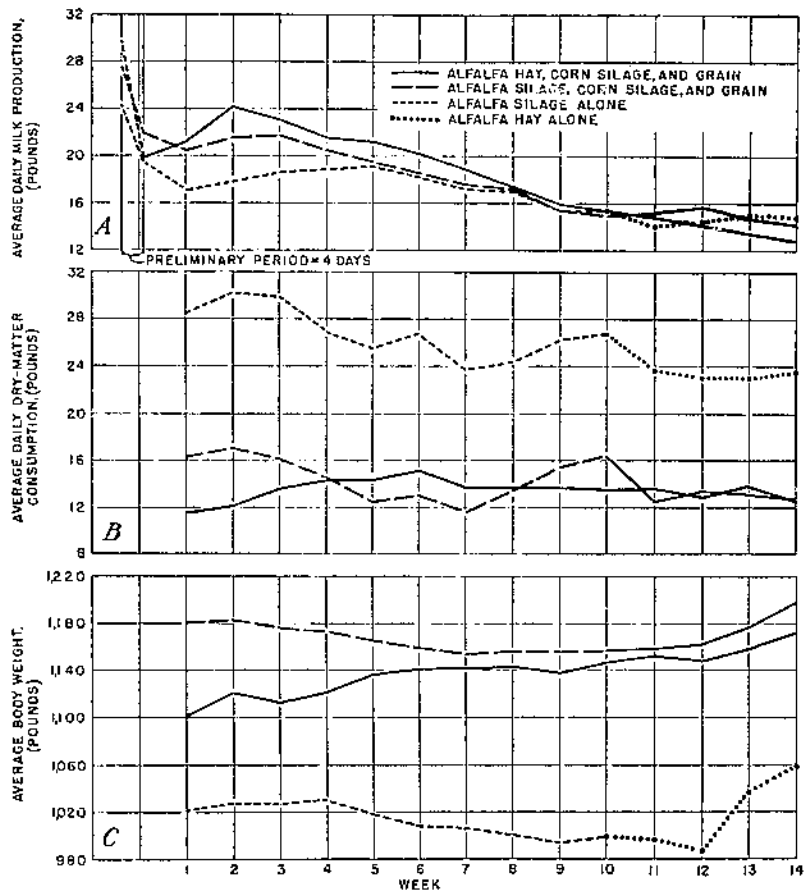

FIGURE 1.—Average milk production (*A*), dry-matter consumption in alfalfa silage or hay (*B*), and body weights of cows (*C*) fed alfalfa silage alone followed by hay alone, or alfalfa silage or hay in the mixed ration.

INFLUENCE OF ALFALFA SILAGE ON THE FLAVOR AND ODOR OF MILK

A short experiment was planned to determine whether alfalfa silage affects the flavor and odor of milk and, if so, whether these flavors are transmitted through the cow, or whether they are absorbed by the milk after it is drawn.

The cows were fed enough alfalfa silage so there was some in their mangers nearly all the time. They continued to eat small quantities from time to time in the interval between milkings. The air in the mangers was always heavily laden with silage odors so that the cows

were compelled to breathe these odors. It has been found that certain odors can be transmitted to the milk by way of the lungs as well as through the digestive tract. For these reasons, it is thought that the effect, if any, on the milk would be similar to that of feeding the silage shortly before milking.

Milk from cows in another barn where no alfalfa silage was being fed was used as a check. In order to determine whether the milk would absorb the silage odors from the air, a portion of the milk from these same cows was poured back and forth through an atmosphere heavily charged with the odors of alfalfa silage.

The silage used for this work was made in 1936 from high-moisture alfalfa. Some of it had as strong odor as any that had been made recently from chopped material. Further information regarding this silage is given in table 2, ninth trial, and the discussion of that trial. The results of this work are presented in table 6.

TABLE 6.—*Opinions of 4 observers on milk from cows fed silage, on milk exposed to silage odors, and on milk which had no opportunity to acquire silage flavors or odors* [1]

SILAGE WITH NOTHING ADDED

Milk from cows fed alfalfa silage as rated by—					Milk exposed to silage odors as rated by—					Milk from check group of cows as rated by—				
Milk of cow No.—	Observer—				Milk of cow No.—	Observer—				Milk of cow No.—	Observer—			
	1	2	3	4		1	2	3	4		1	2	3	4
A–107	N	F	H	------	862	SlF	Str	SlF	------	862	N	N	N	------
840	F	Sl	SlF	------	1215	F	Sl	SlF	------	1215	Tr	Sl	N	------
880	F	Str	F	------	1233	SlF	Str	N	------	1233	N	N	N	------

SILAGE WITH ACID ADDED

A–107	N	N	N	N	862	F	F	F	F	862	SlF	Sl	Sl	N
840	N	N	N	N	1215	N	Sl	N	VSl	1215	VSlF	N	VSl	VSl
880	F	Sl	VSl	VSl	1233	VSlF	Sl	F	F	1233	VSlF	Sl	Sl	VSl

SILAGE WITH MOLASSES ADDED

A–107	F	F	F	------	862	SlF	SlF	VSlF	------	862	N	N	VSlF	------
840	VSlF	VSlF	VSlF	------	1215	VSlF	SlF	F	------	1215	VSlF	VSlF	N	------
880	SlF	SlF	SlF	------	1233	SlF	VSlF	N	------	1233	N	N	VSlF	------

[1] F=feed, H=highly acid, N=normal, Sl=slight, Str=strong, V=very, Tr=trace.

The data show that the observers found many off-flavors in the unexposed milk from the check group of cows, although this milk was intended to be as free from off-flavors as it could be obtained practically.

When the experimental cows were fed the alfalfa silage that was made with nothing added, the off-flavors in the milk were more pronounced than in the unexposed milk of the check group, but perhaps not more so than in the exposed milk of the check group.

When the cows were fed the silage made with acid added, their milk had a better flavor than that from the check group, whether such milk was exposed or unexposed to silage odors. The unexposed milk appeared to be slightly better than the exposed.

When the cows were fed the silage made with molasses added, their milk had somewhat more pronounced off-flavors than the unexposed milk from the check group; it also appeared to have slightly more off-flavors than the exposed milk from the check group.

The general conclusion from this work is that alfalfa silage having a clean acid odor will not injuriously affect the flavor and odor of the milk. Alfalfa silages having strong odors, as of butyric acid, will injure the flavor and odor of the milk either when the silage is fed or when the milk is exposed to the silage odors. In this experiment, however, the off-flavors in most of the samples were not pronounced. For this reason, it is thought that if the precautions advised for the feeding of other kinds of silage are exercised in the feeding of alfalfa silage, there is not likely to be any trouble from off-flavors.

DISCUSSION

It is apparent that the exclusion of air is the only condition required to prevent molding or rotting of silage. The extent and character of the fermentation, however, is profoundly affected by the moisture content of the material. The higher the moisture content the more extensive the fermentation and the greater the likelihood that objectionable odors will develop.

The presence of acids, whether they are developed through fermentation or added as such, also influences the character of fermentation, but acids apparently are not required to protect the silage against loss through molding or rotting. High-moisture silages with a low acidity are likely to have objectionable odors; low-moisture silages with a low acidity will not develop bad odors. If crops with a high moisture content, especially the legumes, are to be siloed, then steps should be taken to bring about quick acidification of the silage, but if crops with a moisture content below 70 percent are to be siloed, then there is no apparent advantage in acidification.

This investigation has demonstrated that hay crops dry enough to be placed in the mow or stack can be preserved successfully in the silo. It is evident that with proper attention to forcing out the air from the silo contents and thereafter keeping it out, hay may be kept effectively in the silo whether the moisture content is 10 or 70 or any intermediate percentage. However, because of the practical difficulties of excluding the air from low moisture material in most silos, it is recommended that the moisture should not fall below 50 percent. If silos with walls and doors more nearly airtight come into use and if a practicable method of weighting and sealing the top is devised, it appears that material with less than 50-percent moisture may be siloed with every assurance of success.

Grasses can be siloed alone or along with legumes almost as readily as corn. The addition of acid to such silage does more harm than good, and the addition of molasses is not necessary, though it may help if the moisture content of the crop to be siloed is very high. The material must be chopped and packed in a way to exclude the air, and, if feeding of the silage does not begin within a few weeks the application of weight, especially near the wall, appears advisable. If the material is low in moisture content, the weight should be applied no matter how short the interval is between filling and feeding.

Legume silages present a harder problem. If the moisture content is high, say above 70 percent, the legumes may make ill-smelling silages. Apparently these odors are more objectionable to the persons handling the silage than they are to the cows. Nevertheless, no one would dispute the desirability of eliminating these odors if it can be done without expense and without introducing other objectionable features. There is a progressive increase in the strength of the silage odors with an increase in the moisture content, but it is not until the moisture approaches 70 percent that the odors are likely to be objectionable. Another way to avoid the development of bad odors besides partial drying is to add dilute acids. Evidence secured in other investigations indicates that molasses also is useful in this respect.

The acids are destructive to any sort of concrete or masonry construction, they are expensive to buy, inconvenient to apply, and they lower the palatability of the silage. To offset these disadvantages the silage possesses a clean acid taste and the carotene, as commonly determined at present, is more effectively preserved. The use of acid may be practicable for the dairy farmer using a wooden or trench silo, provided he must have a high-carotene feed regardless of expense. On account of the greater palatability of the untreated silage it would be easy to bring about as great or greater ingestion of carotene by feeding untreated silage as by feeding acid-treated silage. It might be possible, therefore, to put more carotene into the milk by feeding untreated silage than by feeding silage treated with acid.

The use of molasses is based on the premise that acids are essential for the development of desirable fermentations, and that the sugars of molasses will be converted into acids. Molasses increases the acidity only slightly but apparently enough to improve more or less the odor of high-moisture silages, particularly legume silages. Its use does not lessen the loss of feed constituents, but it does slightly improve the palatability of silages. Molasses is inconvenient to apply and difficult to distribute evenly. However, it is not destructive in any way and it does have nutritive value. In case one is intent upon making silage with a high content of carotene, particularly from legumes, it is suggested that the crop be put in the silo immediately after it is mowed and that molasses be used to improve the odor of the silage.

PRACTICAL CONSIDERATIONS

The easiest and most practicable method of making silage from hay crops is to allow the crop to dry enough so that the content of moisture is between 50 and 70 percent. Most crops at the stage of maturity at which they are usually harvested contain 75 to 80 percent of moisture if there is plenty of moisture in the soil. Wilting for 2 to 4 hours on a good drying day will be sufficient. If the crop is harvested during a dry spell of weather and especially if it is rather mature, the moisture will be low enough so that the crop can be put in the silo directly without wilting. Chop it fine, one-fourth inch if possible. Use a jointed pipe distributor inside the silo and pack the material uniformly. Because of the tendency for silage made from hay crops to draw away from the walls and admit air, it is suggested that keeping the center higher than the sides and especially well packed during the process of filling may help to slide the silage toward the wall as it settles. Complete the filling with a few loads of the heaviest material available and

weight the top, especially around the walls. There is some evidence that hay with 40- or 50-percent moisture is more difficult to chop than that which is either greener or drier.

If one considers carotene preservation to be of primary importance, as may be the case with certain dairies supplying special milk, then the crop should be harvested at an immature stage and placed in the silo immediately. Acid should be added. If one is willing to sacrifice some of the carotene and at the same time run the risk of impairing the odor of the silage in order to have a more palatable silage, then molasses may be used instead of the acid. If one is willing to sacrifice still more of the carotene in order to have a still more palatable silage and at the same time be better assured of a silage with a good odor, then partial drying should be practiced instead of adding molasses. Ease of handling the crop, the cash outlay for materials to be added, and the palatability of the silage are of more importance usually than the preservation of a somewhat higher proportion of carotene. The percentage of carotene in the ration that cows can utilize and transmit to the milk is very small, and the percentage utilized decreases as the amount in the ration increases. For this reason, securing a slightly higher percentage of carotene in a ration that carries adequate amounts, does not appear essential if the increased amount involves considerable increases in labor or expense.

SUMMARY

Data regarding silage made from grass alone or from grass and legumes are based on 19 fillings of small silos—4 feet in diameter by 8 feet high—and 2 fillings of silos 14 feet in diameter.

All feeding and palatability tests were made with dairy cattle.

Chopping the material before putting it in the silo permitted much more to be stored in the same amount of space than nonchopping. It reduced the losses of dry matter. The chopped silage was superior to the long silage in palatability and general appearance. Furthermore, the easiest way to put material in a tower silo is to run it through a chopper and blower.

Fresh, green grass, either alone or mixed with legumes, when chopped and placed in the silo with no other treatment, made a silage that was highly palatable and possessed an agreeable odor. Furthermore, the losses of dry matter and carotene were low.

Partial drying before chopping facilitated handling, increased the quantity of dry matter that could be stored in a given space, increased the surface spoilage, increased the temperature of fermentation as much as 12° F., and in most cases improved the palatability as judged by the quantities of dry matter that cows would consume.

Immature grasses made a more palatable silage than mature grasses, just as immature grasses make more palatable hays.

Mixtures of unpalatable grasses with legumes were made into silage which was considered equal in palatability to that of hay made from similar mixtures.

Good grass silage was quite palatable. Cows ate it in about the same quantities that they would graze the grass from which the silage was made.

The addition of acids to grasses or to mixtures of grasses and legumes in which the grasses predominated lowered the palatability

of the resulting silages. This was compensated for in part by a slightly more effective preservation of the dry matter and carotene. The addition of molasses improved the palatability slightly, but in other respects it did not prove advantageous. It should be noted, however, that molasses was not added to any grasses with a high content of moisture.

The spoilage of grass silage in large silos filled with little distributing or packing was excessive. This was caused by the silage shrinking or settling away from the walls, thus admitting air.

The experimental results with legume silage are based on 16 fillings of small silos and 1 filling of a large silo.

Fresh, green alfalfa placed in the silo with no treatment other than chopping kept without molding or rotting. The dry matter, protein, and carotene were satisfactorily preserved, but the silage though usually eaten readily appeared less palatable than grass silage made in a similar manner. The odor of the silage was not objectionable when the dry matter of the crop was as much as 30 percent, but when it was less than 30 percent the silage usually developed offensive odors.

Partial drying of legumes before chopping for the silo increased the surface spoilage, increased the temperature of fermentation as much as 9° F., and improved the palatability of the silage.

It was found that the odor of the silage could be improved by partial drying before chopping or by the addition of dilute acids. The odor of laboratory specimens with a high moisture content in another investigation was also improved by the addition of molasses.

Dilute acids lowered the palatability of the silage to a marked extent. They appeared to favor the preservation of carotene and nitrogen but had little effect on the losses of dry matter. They depressed the temperature of fermentation slightly.

Molasses had a slight effect in increasing the losses of dry matter, protein, and carotene, and in improving the palatability. It lowered the pH value an average of 0.27 for all silages.

Experiments with makeshift pits showed that unchopped, green alfalfa could be made into acceptable silage provided that the moisture content was not too high. Silage saturated with drainage water was particularly offensive.

Alfalfa silage on the basis of dry-matter content, when fed either alone or with corn silage and grain, appeared to be fully equal to alfalfa hay for the production of milk but inferior to the hay for the maintenance of body weights.

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