STUDIES IN THE CHEMISTRY OF GRASS SILAGE[1]

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INTRODUCTION

In connection with an attempt to find substitutes for molasses as preservatives for silage in our wartime economy, and to ascertain whether good quality grass silage could possibly be made without any preservative, a rather extensive study of the biochemistry of numerous kinds and types of silage was carried on during the seasons 1942–43 and 1943–44.

The literature of silage making is voluminous and no good purpose would be served by attempting to review all or even any considerable part of it here. The reader is referred to reviews by Bender and Bosshardt (*2*),[2] Hopkins and Ripley (*5*), LeClerc (*6*), and Woodward and Shepherd (*18*). Earlier chemical studies are confined pretty largely to routine fodder analyses which, while they furnish information on feeding value, shed little light on the fermentation process or on those end products (especially volatile acids and ammonia) which determine the quality and palatability of the silage. Noteworthy exceptions to this statement are the work of Dox and Neidig (*3*, *4*), Neidig (*9*), and Swanson and Tague (*15*), although Dox and Neidig worked only with the corn plant. Recent contributions on the subject which are of significance here include the work of Watson and Ferguson (*17*), Perkins (*11*, *12*), and Stone et al. (*14*).

EXPERIMENTAL METHODS AND MATERIAL

Forty samples of silage representing various crops and treatments were analyzed to determine moisture content, pH values, total nitrogen, water-soluble nitrogen, carotene, volatile bases, total acidity, amino acids, lactic acid, acetic acid (total and free), and butyric acid (total and free). In addition, the first five of the above entities were determined in nine samples of the fresh green crops before ensiling. The methods used were: For moisture, the Brown-Duvel toluene distillation procedure as modified by the Association of Official Agricultural Chemists (*1*, *p. 353*); pH values, a water extract of the finely chopped silage, using a Coleman pH meter with glass electrode; total nitrogen in the fresh sample by the usual Kjeldahl procedure; water-soluble nitrogen, the method of Watson and Ferguson (*17*); carotene, the method of Wall and Kelley (*16*); volatile bases, total bases, total

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[2] Italic numbers in parentheses refer to Literature Cited, p. 287.

acidity, and amino acids by the method of Foreman as outlined by Watson and Ferguson (*17*); acetic and butyric acids by the method of Wiegner as given by Watson and Ferguson (*17*); and lactic acid by difference as suggested also by these workers, i. e., total acidity—(amino acids+acetic acid+butyric acid)=lactic acid. In addition to the above the customary fodder analyses were also made.

In sampling from the large silos on the college farm small handfuls of silage were taken here and there over the entire area of a freshly exposed surface, sufficient to fill a friction-covered tin pail of 6-quart capacity. Samples submitted from farms were usually of much greater volume (a bushel or more), thus affording an opportunity for careful subsampling. Samples from the miniature silos were taken from all through that part of the mass of silage which was not obviously spoiled by rot or mold. All determinations except fat, fiber, and ash were made on the fresh samples finely chopped with scissors just before weighing. Total nitrogen was determined in both fresh and dry material.

The samples may be divided into 3 lots: (1) A series of 20 samples (16 of silage and 4 of fresh unensiled crops) which were obtained in a study of 2 crops treated with various preservatives in miniature silos, during the season of 1942–43; (2) a series of 19 samples of different origin and nature, obtained also in 1942–43, 13 of which were sent in by cooperating farmers [3] interested in the project, the other 6 being obtained from the large silos on the college farm; and (3) a series of 10 samples (5 of silage and 5 of the corresponding crops before ensiling) obtained from 1 of the large silos on the college farm during the season of 1943–44.

As already noted, the first lot of samples came from miniature silos. The objective of the study with these was to ascertain whether results might be obtained from small containers which would be similar to those secured from large silos. Statements in the literature are conflicting on this point; it is obvious that if small containers could be used with confidence in the results obtained, progress toward the main objectives of the investigation would be greatly accelerated.

The containers employed for the purpose were heavy glass cylinders, 9.5 inches inside diameter, and 39 inches high, open at both ends. The volume was slightly under 1.5 bushels. Sixteen such containers were used in accordance with the schedule in table 1. They were subjected to as much pressure as was practicable (120 pounds per square foot) and were kept in a darkened room.

The second lot of samples was obtained for the most part without resort to any special experimental set-up. All were from large silos (100 tons capacity or more) and represented conditions regularly existent in practical operations. Two of them can be compared with certain samples in the previous group; they were from the same lot of mixed grass ensiled at the same time, the only difference being that they were from 100-ton silos on the college farm. Thus a direct comparison was provided between large silo and small container on the same lot of grass and with the same preservative.

[3] Acknowledgment is made of the cooperation of these men and more especially, of the interest taken by Herbert A. Brown, county agricultural agent at Concord, Mass., who was instrumental in obtaining the samples.

TABLE 1.—*General outline and sample identification* [1]

LOT 1 (FROM MINIATURE SILOS)

Mixed grasses: [2]
1. The fresh, unensiled crop; Nos. 5, 6, 7, and 8 represent the ensiled product.
2. As in 1; Nos. 9, 10, 11, and 12 represent the ensiled product.

Alfalfa: [3]
3. Unwilted. The fresh crop; Nos. 13, 14, 15, 16, and 17 represent the ensiled product.
4. Wilted for 27 hours; Nos. 18, 19, and 20 represent the ensiled product.

Mixed grass silage:
5. No preservative.
6. Lactic acid culture—66 lbs. (*Lactobacillus bulgaricus*).
7. Salt—18 lbs.
8. Lactic acid culture and salt.
9. As in No. 5 plus a little water.
10. As in No. 6 plus a little water.
11. As in No. 7 plus a little water.
12. As in No. 8 plus a little water.

Alfalfa silage:
13. Unwilted. No preservative.
14. Unwilted. Lactic acid culture.
15. Unwilted. Molasses—90 lbs.
16. Unwilted. Salt.
17. Unwilted. Lactic acid culture and salt.
18. Wilted. No preservative.
19. Wilted. Lactic acid culture.
20. Wilted. Molasses.

LOT 2 (MISCELLANEOUS SAMPLES—ALL SILAGES)

Mixed grasses:
21. No preservative. Similar to 5 and 9, except from a large silo.
22. Lactic acid culture. Similar to 6 and 10, except from a large silo.
23. Lactic acid culture and salt—15 lbs.
24. Molasses—40 lbs.

Mixed grass and clover:
25. Lactic acid culture and salt—8 lbs.
26. Molasses—50 lbs.

Timothy and clover:
27. No preservative.
28. Molasses—amount not known.
29. Molasses—35 lbs.

Oats:
30. No preservative.
31. Lactic acid culture and salt (16 lbs.)

Oats and peas:
32. No preservative } From the same silo 7 weeks
33. Do. } apart.
34. Salt—10 lbs.

Winter wheat:
35. Salt—a pailful to a load.

Soybeans:
36. Molasses—amount not known.

Sudan grass, millet, and sorghum:
37. Molasses—amount not known.

Corn:
38. No preservative } Included for comparison.
39. Do. }

LOT 3 (FROM LARGE EXPERIMENTAL SILO)

Mixed grass and clover:
40. The freshly chopped crop after preservative has been added, but before ensiling.
41. Do.
42. Do.
43. Do.
44. Do.
45. Molasses (75 lbs.) and urea (10 lbs.). No. 40 after ensiling.
46. Urea (10 lbs.) No. 41 after ensiling.
47. Ground wheat—100 lbs.—No. 42 after ensiling.
48. Ground wheat—150 lbs.—No. 43 after ensiling.
49. Ground wheat—200 lbs.—No. 44 after ensiling.

[1] Amounts of preservative given are per ton of green crop; where not stated they are the same as previously noted in the lot in question. In the large silos lactic acid culture was applied at several levels, being first diluted with water; a sprinkling can full of the diluted culture was used at each level.
[2] Headed to some extent but not in bloom.
[3] In full bloom.

The third lot was from a definite experimental set-up in a 100-ton silo; five different lots of silage were treated as outlined in table 1. Assurance that each sample of silage would represent material identical, or nearly so, with that of the corresponding sample of fresh crop taken at filling time was provided for by the following procedure: A sample of the freshly chopped crop to which the specific preservative had been added in routine fashion was taken from the silo about midway of each lot; at the same time a clean burlap grain sack was filled with the same material as the sample, and, properly tagged, was buried in the center of the silo. From each sack when reached as the several lots were fed, the corresponding silage sample was secured. Table 1 outlines the scope of the work and serves to identify the several lots and samples.

CHEMICAL ANALYSES

Limitations of space preclude presentation here of the large accumulation of detailed data. Instead, general summaries and emphasis on high lights and on significant differences are depended upon to tell the story. It may be of interest to note in passing that the work involved over 800 chemical determinations (not counting parallels) in addition to several hundred other observations most of which were organoleptic. All values except moisture, pH, and carotene are reported as percentages in the dry substance; the first two exceptions are of course the values for the fresh silage; the carotene values are expressed as milligrams per pound of dry silage. Not all of the various entities determined are reported; it became evident upon critical examination that some of them showed only minor variations from sample to sample, and hence contributed nothing of significance to the findings. Table 2 summarizes the results from two standpoints—variation due to (1) kind of crop ensiled, and (2) kind of preservative used.

TABLE 2.—*Composition of silage as influenced by kind of crop and by preservative used* [1]

Crop ensiled and preservative used	pH	Volatile bases [2]	Total acidity [3]	Lactic acid	Acetic acid	Butyric acid	Carotene
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Mg. per pound*
Crop:							
Alfalfa	4.5	0.76	14.41	4.75	5.49	0.66	46
Mixed grasses	5.2	1.49	11.43	.16	1.84	7.29	80
Mixed grasses and clover	4.6	.76	9.63	3.64	1.50	2.98	68
Timothy and clover	4.5	.78	12.13	3.26	3.52	2.80	77
Oats	5.2	.60	7.65	2.06	1.65	2.40	33
Oats and peas	4.5	.46	10.96	3.96	2.66	.50	39
Winter wheat	5.4	.81	11.28	None	2.26	6.83	117
Sudan grass, millet, and sorghum	4.5	.58	9.66	1.13	2.28	4.42	13
Soybeans	4.3	.54	13.00	4.73	4.42	1.64	28
Corn (included for comparison)	3.8	.26	14.64	7.58	5.22	None	27
Preservative:							
None [4]	4.8	.92	11.26	2.58	2.69	2.87	58
Lactic acid culture	4.7	1.14	12.89	2.62	3.27	4.21	63
Salt	5.0	1.08	11.61	1.04	2.88	5.13	77
Lactic acid culture and salt	5.3	1.14	11.23	.19	3.34	5.38	63
Molasses	4.5	.74	12.48	4.26	3.21	3.04	62
Molasses and urea	5.2	1.70	10.63	4.16	1.92	2.74	63
Urea	5.6	3.80	13.11	None	5.68	6.44	130
Ground wheat	4.3	.50	9.02	5.06	1.04	2.49	54

[1] The values in this table are composites, and include all samples listed under the specific corresponding category in table 1.
[2] Volatile bases are expressed as percentage of ammonia in the dry substance.
[3] Total acidity is expressed as the weighted percentage of amino, lactic, acetic, and butyric acids in the dry substance of each sample, based on the molecular weights of the acids in question. (Amino acids were calculated as an average of aspartic and glutamic acids, based on their molecular weights.)
[4] Does not include the values for corn silage.

Variations due to the crop used were more significant than those due to the action of preservatives. The principal points of interest are:

(1) In general the legume silages developed a higher acidity than those made from grasses or small cereals; also the presence of a legume in a mixture resulted in higher acidity. The inverse relationship held true for volatile bases, which is what would be expected.

(2) For the most part also the legumes developed a higher total acidity. Differences, however, are more evident in the type of acidity than in the total amount. The legume silages were characterized by a relatively high content of lactic and acetic acid and their influence

in this respect is also evident in the mixed crop silages; the grass silages and certain of the small cereals, on the other hand, had a relatively high butyric acid content and little or no lactic acid.

(3) The two lots of corn silage offer a striking contrast to the grass silages in their low pH, values very low volatile base content, high lactic and acetic acid, and absence of butyric acid. This seems an appropriate point at which to make the general observation that the most strongly acid-smelling silages have frequently been the least acid, as judged either by pH or by total acidity as determined by titration. This may seem paradoxical until one considers that the type of fermentation which develops butyric acid is likely also to develop more ammonia and other bases which neutralize a portion of the acid and keep the pH relatively high and the titration values low. The better quality silages with mild, pleasant odor were almost invariably more acid than those which sense of smell alone would rank as much more acid. The acid in the better quality silages was largely lactic, which is nonvolatile and of relatively mild odor, and their volatile base content was usually quite low.

(4) Of the preservatives used molasses and ground wheat seem to have been the only ones that were at all effective. They kept the break-down of protein at a relatively low level, as evidenced by low content of volatile bases; favored the formation of lactic acid; and limited the formation of butyric acid. Salt and lactic acid cultures were in many respects worse than no preservative at all; they encouraged the formation of volatile bases and butyric acid and inhibited the development of lactic acid, some of the samples showing none at all. Urea was evidently entirely unsuited to the purpose; the idea in using it was to increase the nitrogen content of the silage and hence the potential protein level for ruminants. It seems apparent from the high pH and the very high content of volatile bases in this lot of silage that a considerable portion of the urea must have been converted into ammonia. That some of it was lost by leaching is evident from the increased nitrogen content of the leachings from this particular silo. The average figure for 4 years previously was 0.30 percent nitrogen; when urea was used it rose to 0.56 percent. The silage made with urea alone as a preservative had a very objectionable odor and was unpalatable to milking cows. The silage made by using ground wheat as a preservative had a mild, pleasing odor and was very palatable. The herdsman in charge observed that it was the best quality grass silage he had fed in our 8 years of experience. In table 3 is presented a summary of the proximate analyses,[4] together with some interesting contrasts between certain of the silages and the fresh crops from which they originated.

Changes in composition due to the silage fermentation show a definite trend regardless of the nature of the crop ensiled. Relatively the greatest losses are in carotene and the greatest gains are in ether extract. The gains in ash and fiber doubtless are apparent only, because of losses of a similar magnitude in protein and nitrogen-free extract. The gain in ether extract is actual, since the organic acids formed by fermentation from the carbohydrates are ether-soluble,

[4] Acknowledgment is made of the services of Albert F. Spelman, assistant chemist, and Leo V. Crowley and C. Tyson Smith, junior chemists, in the Feed Control Laboratory of this station, who made the fodder analyses under the direction of John W. Kuzmeski, senior chemist, and Philip H. Smith, chief chemist.

whereas carbohydrates are not soluble in anhydrous ether. High carotene values did not necessarily occur in silages that were of good quality in other respects; e. g., note the very high value for the winter wheat silage. In most other respects this was about the poorest quality silage examined; a similar condition was noted in a lot of mixed grass and clover preserved with urea (see table 2). Stage of maturity of the crop probably had a good deal to do with this. In the case of the silage preserved with urea it may be that the type of fermentation induced by the high pH altered certain noncarotene pigments sufficiently to permit their estimation as carotene.

TABLE 3.—*Average proximate composition of silages from various crops and crop combinations, and of some fresh, unensiled crops from which certain of the silages were prepared* [1]

Kind of crop	Moisture as sampled or received	pH	Carotene	Percentages in the dry matter				
				Total ash	Crude protein	Crude fiber	N-free extract	Ether extract
	Percent		*Mg. per pound*					
Alfalfa	62.3	6.0	133	7.3	17.8	35.7	37.4	1.8
Alfalfa silage	68.2	4.5	46	9.3	16.8	38.5	32.8	2.6
Grasses, mixed	75.0	6.1	157	7.3	12.8	33.9	43.3	2.7
Grasses, mixed, silage	74.8	5.2	80	[2] 10.2	10.0	38.7	38.0	3.1
Grasses and clover	68.1	6.2	58	8.0	12.1	32.8	44.9	2.2
Grass and clover silage	68.9	4.6	68	7.8	10.5	37.2	41.0	3.5
Timothy and clover silage	73.8	4.5	77	10.6	12.9	34.7	38.8	3.0
Oat silage	70.6	5.2	33	9.2	9.1	38.0	40.3	3.4
Oat and pea silage	67.3	4.5	39	8.7	10.4	35.8	41.7	3.4
Winter wheat silage	73.9	5.4	117	12.6	8.0	41.4	34.5	3.5
Sudan grass, millet, and sorghum silage	79.7	4.5	13	7.9	4.6	44.5	40.9	2.1
Soybean silage	71.0	4.3	28	19.7	10.9	30.4	37.2	1.8
Corn silage (for comparison)	74.2	3.8	27	6.0	8.4	35.3	47.6	2.7

[1] The values in this table are composites, and include all samples listed under the specific corresponding category in table 1.
[2] This figure is due in part to the use of salt in some of the silages.

Table 4 shows the composition of material ensiled in the miniature silos referred to earlier in comparison with material from the same lot of grass ensiled with the same treatment in two 100-ton silos. Except for carotene the differences are rather small; what there are indicate that fermentation took place on a more extensive scale in the large silos. The differences in carotene content are arresting; if typical of what may occur in large silos they represent a need for further investigation in order that such excessive losses of this important nutrient may be prevented. These losses are on a par with those occurring in dry hay. It should be mentioned that the small containers did not prove satisfactory. Spoilage losses were high in most of the containers, averaging over 18 percent, due chiefly to rotting of the upper layers. In the containers in which wilted alfalfa was stored the losses were excessive, averaging over 60 percent, due to penetration of mold. Fermentation losses were normal in most cases, averaging about 9 percent with some under 5 percent. Evidently conditions existent in a large silo are not readily duplicated on a small scale.

TABLE 4.—*Composition of silage from the same lot of grass ensiled in small silos (1.5 bushel capacity) and large silos (100 tons capacity)*

Type of silo and treatment of silage	Moisture when sampled	pH	Carotene	Percentages in the dry matter									
				Volatile base	Total acidity	Lactic acid	Acetic acid	Butyric acid	Total ash	Crude protein	Crude fiber	N-free extract	Ether extract
	Pct.		*Mg. per pound*										
Small silos—no preservative	78.3	5.1	107	1.74	12.15	None	1.92	7.89	7.6	10.2	38.0	40.6	3.6
Large silos—no preservative	73.4	5.4	25	1.59	13.22	None	.80	8.08	8.7	9.2	40.4	38.2	3.5
Small silos—lactic acid culture	76.4	5.0	84	1.44	10.91	None	2.15	7.55	8.9	10.3	38.8	39.0	3.0
Large silos—lactic acid culture	71.4	4.9	32	1.36	12.61	0.73	2.46	5.70	9.8	9.3	39.8	37.9	3.3

In table 5 appear the contrasts in composition due to wilting of alfalfa. Changes in composition before ensiling caused by wilting seem to have been confined to a material reduction in carotene content and to rather minor and probably only relative increases in protein and nitrogen-free extract with a corresponding reduction in fiber. Changes after ensiling are of much more significance; note especially the lactic acid-acetic acid relationship in the wilted and unwilted silage, and the much lower fiber and higher protein and nitrogen-free extract of the wilted silage. Insofar as these silages are concerned wilting resulted in a very different type of fermentation and final product. It may be that the influence of mold enters in here; the excessive development of mold in the wilted silages has been mentioned already, but it should be noted that care was taken to discard all visible signs of mold when the samples were taken for analysis.

CHLORIDE CONTENT OF SILAGE

In the course of the work the question arose as to whether the practice of using salt as a silage preservative might not at times introduce an excessive amount into the rations of livestock, and this in turn suggested the need to know how much salt (or total chlorides) occurs in silage naturally. A search of the literature showed very little information on this point, so a determination of the chloride content of these 40 silages was made a part of the routine procedure. The determination was made on suitably diluted duplicate aliquots of the water extract by titration with N/10 silver nitrate. A 10-percent solution of potassium chromate was used as indicator, the end point being determined by the first permanent color change visible against the background of a glazed white porcelain evaporating dish. The results are summarized in table 6.

The chloride values were highest in the silages made from small grains and lowest in those made from legumes. Salt increased the chloride content to a value about 2½ times that found in the silages with which no preservative was used. Other preservatives were without substantial effect. Consideration of the effect of the added salt upon feeding practice and animal health is appropriate here.

TABLE 5.—*Composition of alfalfa, wilted and unwilted, and of the corresponding lots of silage made from it*

Alfalfa	Moisture when sampled	pH	Carotene	Percentages in the dry matter									
				Volatile bases	Total acidity	Lactic acid	Acetic acid	Butyric acid	Total ash	Crude protein	Crude fiber	N-free extract	Ether extract
	Percent		*Mg. per pound*										
Unwilted—before ensiling	73.5	6.0	156	(1)	(1)	(1)	(1)	(1)	7.4	17.1	37.5	36.3	1.8
Wilted—before ensiling	49.0	6.0	110	(1)	(1)	(1)	(1)	(1)	7.2	18.4	34.0	38.7	1.7
Unwilted—after ensiling	77.7	4.6	49	0.98	15.58	2.68	8.15	0.66	9.9	15.7	41.6	30.0	2.8
Wilted—after ensiling	52.5	4.2	40	.38	12.47	8.20	1.05	None	8.2	18.6	33.4	37.6	2.2

[1] Not determined.

TABLE 6.—*Average chloride content of different kinds of silage*

Crop [1]	Chlorides in the dry matter [2]	Preservative	Chlorides in the dry matter [2]
	Percent		*Percent*
Alfalfa	0.80	None	1.10
Mixed grasses	1.13	Lactic acid culture	1.03
Mixed grasses and clover	1.06	Salt	2.77
Timothy and clover	1.26	Lactic acid culture and salt	2.46
Oats	1.56	Molasses	1.09
Oats and peas	1.19	Molasses and urea	1.17
Sudan grass, millet, and sorghum	1.43	Ground wheat	.88
Soybeans	.21		
Corn	.54		

[1] All samples in which salt was used as a preservative have been excluded from the average values for the several crops.
[2] To convert these values to terms of NaCl, multiply by 1.65; to convert them to an average basis of fresh silage as fed, multiply by 0.3.

A little calculation shows that from the silages preserved with salt a cow consuming 40 pounds of fresh silage daily would get 0.55 pound of salt daily from this source alone. Assuming that she also consumes 10 pounds of a grain mixture with its usual salt content of 1 percent, she would get from these two sources somewhat over 10 ounces of salt daily; there is also the unknown quantity contained in whatever other roughage she might consume (a cow eating 40 pounds of silage usually eats 10 to 12 pounds of dry hay in addition). Information in the literature as to the amount of salt a cow requires is very meager; Maynard (*7, p. 435*) makes the statement that "One to two ounces of salt daily should be adequate for milking cows." Although undoubtedly cows can tolerate somewhat larger amounts than this, it is extremely doubtful whether they should receive for any considerable length of time as large an amount as 10 ounces daily. Furthermore, this is based on only the average amount found in the samples to which salt had been added; the maximum amount of chlorides found was 4.14 percent in the dry matter. Figured on the same basis as above a cow's daily salt intake on this particular lot of silage would be approximately 14 ounces; undoubtedly this is excessive.

EVALUATION OF CERTAIN METHODS

In the course of the investigation there were opportunities to compare certain analytical procedures, notably those dealing with the determination of total nitrogen and with carotene.

It has been recognized for years that in general considerable losses of nitrogen occur in all types of biological material if it is dried and ground, as for routine fodder analyses, before determining total nitrogen. Yet one finds in the literature instances of recent work where this fact has been ignored. For comparative purposes total nitrogen was determined in the fresh material immediately upon its receipt at the laboratory and again after drying and grinding. Carotene was determined by the phasic separation procedure outlined in the Official Methods (*1*) and by the chromatographic method described by Wall and Kelley (*16*).[5] The results are shown in table 7.

Considering nitrogen first, the interesting thing is the great variation in the error due to determination after drying. On the whole, it was much larger in the silages than in the unensiled crops, but the average errors for some are so small that they might almost be classed as experimental error; e. g., that for corn or for mixed grass and clover. One might be tempted to place in this class the positive error for silage preserved with ground wheat, except for the fact that it was consistent and the average represents three different lots of silage. Apparently the ground grain served to fix volatile nitrogenous bases and thus to prevent the customary loss on drying. Molasses seems to have had a similar though less marked effect.

TABLE 7.—*Comparison of (a) nitrogen determination, and (b) carotene determination in green crops and in silages by 2 methods*

Material	Percentage of nitrogen in the dry matter		Percentage loss due to drying	Milligrams of carotene per pound of dry matter		Result in (2) is lower by (percent)—
	Determined in the fresh material	Determined in the dried and ground sample		(1) By phasic separation	(2) By chromatography	
Crops before ensiling:						
Alfalfa	3.05	2.85	5.6	(1)	(1)	(1)
Mixed grasses	2.08	2.05	1.4	(1)	(1)	(1)
Mixed grasses and clover [2]	1.91	1.80	5.8	63	58	7.9
Kinds of ensilage:						
Crop:						
Alfalfa	3.10	2.69	13.2	44	36	18.2
Mixed grasses	2.29	1.58	31.0	113	84	25.7
Mixed grasses and clover [2]	1.80	1.76	2.2	103	83	19.4
Timothy and clover	2.25	2.07	8.0	138	93	32.6
Oats	1.76	1.45	17.6	32	30	6.2
Oats and peas	1.77	1.67	5.6	39	19	51.3
Winter wheat	1.97	1.27	35.5	(1)	(1)	(1)
Sudan grass, millet, and sorghum	1.04	.74	28.9	29	13	55.2
Soybeans	2.04	1.75	14.2	56	28	50.0
Corn	1.37	1.35	1.5	46	27	41.3
Preservative:						
None	2.15	1.87	13.0	71	51	28.2
Lactic acid culture	2.63	2.10	20.1	90	59	34.4
Salt	2.43	1.63	32.9	84	67	20.2
Lactic acid culture and salt	2.11	1.52	28.0	89	67	24.7
Molasses	2.37	2.14	9.7	99	70	29.3
Molasses and urea	2.21	1.56	29.4	62	47	24.2
Urea	2.99	1.45	51.5	139	130	6.5
Ground wheat	1.84	1.88	+2.2	68	51	25.0

[1] Comparative figures not available.
[2] For obvious reasons values for those samples of mixed grass and clover to which urea has been added are not included in the averages.

[5] Material assistance rendered and valuable suggestions made by John W. Kuzmeski, senior chemist in the Feed Control Laboratory of this station, are gratefully acknowledged.

Several investigators (*8*, *13*, *16*) have shown that when carotene is determined by alkaline extraction followed by phasic separation as outlined in the official method, varying amounts of noncarotene chromogens remain in the carotene fraction and result in carotene values that are too high. Moore (*8*) in particular has shown that this error is much more significant in silages than in fresh green crops; the results in table 7 confirm and extend his observations. In general, phasic separation gave carotene values about one-third higher than those obtained by chromatography, although the range was wide (from 6 percent to 55 percent higher). Variation was greatest between crops; except for the rather small difference when urea was used, variability in this respect between silages treated with different preservatives was slight, the differences between the two methods being of the same general order (about 25 percent), regardless of preservative used.

SUMMARY

A biochemical study has been made of 40 samples of different kinds of silage stored with various preservatives and of 9 samples of fresh green crops before ensiling which corresponded in identity with certain of the silages.

Variations due to the kind of crop used were more significant than those due to the action of the preservative.

In general legume silages had lower pH values and higher total acidity than silages made from grasses or small grains. The type of acidity also was different; legume silages were characterized by a high lactic acid content while the others showed relatively large amounts of acetic and butyric acids.

The most strongly acid-smelling silages were frequently the least acid, as judged by either pH or total titratable acidity. An explanation of this apparent paradox is offered.

Corn silage offered a striking contrast in composition to grass silage.

Of the preservatives used, molasses and ground wheat seem to have been the only ones at all effective. Salt and lactic acid cultures were in many respects inferior to no preservative at all. Urea was apparently entirely unsuitable for the purpose.

Changes in proximate composition due to the fermentation process showed a definite trend regardless of the nature of the crop ensiled. High carotene values did not necessarily characterize silages that were of good quality in other respects. Carotene losses in some of the large silos were excessive.

Small containers utilized in an effort to speed up the work did not prove satisfactory, losses due to rotting and mold being excessive. Evidently conditions existent in a large silo are not readily duplicated on a small scale.

Silage made from wilted alfalfa was quite different in composition from that made from the unwilted crop.

The chloride content of some of the silages in which salt was used as a preservative was above the optimum for reasonable intake of salt, and in some cases it was excessive.

Losses in total nitrogen, as indicated by determining this element in both the fresh and the dried, ground samples, were very variable, being much higher in the silages than in the corresponding green crops.

Certain preservatives (molasses and ground wheat) tended to minimize this loss.

The chromatographic procedure for determining carotene gave results consistently somewhat lower than those obtained by the official phasic separation procedure.

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