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Feeding Value of Limestone Treated Corn Silages for Fattening Cattle

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FEEDING VALUE OF LIMESTONE TREATED CORN SILAGES FOR FATTENING CATTLE

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Well-eared corn silage is the top producer of beef per acre for corn belt cropland. Returns to farmer-feeders are greatest when liberal amounts of silage are fed with some grain and supplement. When fed in this manner, corn silage has had a higher feeding value than would be estimated by routine feed analyses (11, 14).

Corn, with its solid stems, high carbohydrate content and generally desirable moisture level is an excellent silage crop. Since no special problems have been encountered in ensiling the corn plant, little research has been conducted for possible methods of improving its value.

The process of ensiling corn is characterized by fermentation of carbohydrates to form organic acids, primarily acetic and lactic (1). Feeding trials with lambs and cattle have shown that certain organic acids, especially lactic, have a high feed replacement value (5, 10, 12).

Research a number of years ago (15, 16) showed a high value for ear corn silage when fed to fattening cattle. More recently (2, 9, 3), it has been reported that the dry matter of high-moisture corn stored in silos is utilized more efficiently than that in dry corn.

In the experiments reported in this bulletin the objectives were: (1) To determine the organic acid content of ensiled shelled, ground ear and whole plant corn; (2) To study possible means of increasing organic acid production in whole plant and ground ear corn during ensiling; and (3) to compare the feeding value and digestibility of treated and untreated silages.

PROCEDURE

Materials and Methods of Analysis: In order to determine the organic acid content of various types of ensiled corn, samples of shelled and ear corn stored in silos and fed to cattle in Northwestern Ohio were obtained. Samples were obtained from steel, concrete-stave and air-tight, glass-lined silos.

[1]The assistance of L. E. Kunkle, V. R. Cahill and Paul Althouse who supplied carcass data and of Jack Van Stavern who assisted with a portion of these experiments is gratefully acknowledged.

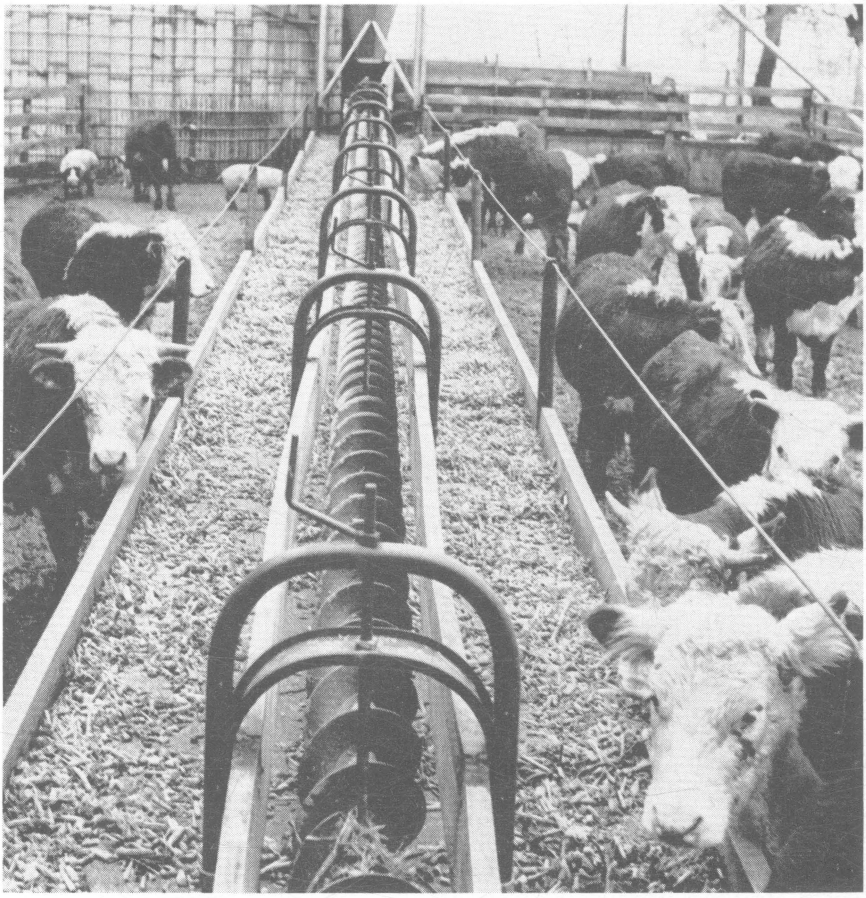
The corn used in the laboratory, feeding and digestion experiments was a yellow, adapted, grain hybrid yielding in the range of 80 to 100 bushels of shelled corn per acre. Laboratory experiments were conducted with three-gallon glass jars fitted with air-tight screw caps. The silages used in the feeding and digestion experiments were stored in conventional concrete-stave or steel silos.

The dolomitic limestone contained a guaranteed 21.5 percent calcium and 12.4 percent magnesium with 75 percent passing through a 100 mesh screen. The high calcium limestone used contained 36.6 percent calcium and 0.29 percent magnesium with 80 percent passing through a 200 mesh screen. Any urea used as an additive was feed grade urea. Other additives used under laboratory conditions included corn distillers' dried solubles, technical grade calcium carbonate, dried molasses product ("Omalass"), and dicalcium phosphate.

Organic acid determinations were made on liquid expressed from the silages by a laboratory hydraulic press. With a few of the drier shelled and ear corn silages it was necessary to homogenize the samples with a known amount of water in order to obtain sufficient liquid for analysis. Acetic and lactic acid contents in the silage expressates or extracts were determined by chromatographic separation on a silica gel column, using the method of Bulen *et al.* (6) as modified by Linke (13). Analyses of feeds and feces were by standard A. O. A. C. procedures except that cellulose was determined by the Crampton and Maynard (8) method.

Laboratory Experiments: Additives used were mixed with the material to be ensiled which was then firmly packed in jars by hand. The jars were sealed and allowed to stand at room temperature for 3 to 6 months. In the first experiments, high-moisture ear corn was prepared by mixing water in the desired amounts with air-dry ground ear corn. In later experiments and when whole plant materials were used, the jars were filled at the same time conventional silos were filled. The entire amount of material ensiled in the jars was subsampled for analysis.

Feeding Experiments: The cattle used in all feeding experiments were choice grade, Hereford steers or heifers obtained from a single ranch in northern Texas. All experiments were conducted with groups of cattle hand-full-fed under practical feed lot conditions. The cattle were assigned to lots at random within weight groups. Average weights and gains of the cattle and daily rations fed are given with tables of results. Soybean oil meal was 44 percent solvent extracted meal.



Corn silage is well adapted to mechanized feeding.

Minerals fed consisted of a mixture of 2 parts steamed bonemeal, 2 parts ground limestone and 1 part salt except when ground limestone had been added to the silage the mineral supplement consisted of 4 parts steamed bonemeal and 1 part salt.

Whole plant silage was cut with a field chopper, hauled in unloading wagons and blown into the silos. Ear corn was picked with a standard picker which removed most of the husks. It was ground with a power take-off burr mill which was set to crush practically all of the kernels. Limestone or limestone and urea were added by scattering over the tops of the loaded wagons or sprinkling on the corn as it was conveyed into the blower. The control and treated ground ear corn

were ensiled in the same concrete-stave silo which was divided by a large sheet of plastic in the middle of the silo. When water was used it was added through a hose at the blower or in the silo. Dry ear corn was ground at the time of feeding with either a hammer mill or a power take-off burr mill.

At the end of each experiment cattle were slaughtered at local packing plants where individual carcass grades and weights were obtained.

Digestion Experiments: Digestion experiments were conducted with wether lambs to determine the effect of added limestone upon the digestibility of the rations fed. Seven-day preliminary and seven-day collection periods were used. Rations fed included the same feeds in similar proportions to those fed in the cattle feeding experiments. To study the effect of limestone upon digestibility of whole plant corn silage, four lambs were used in a reversal experiment in which two lambs were fed each of the treated and untreated silages in two periods. In the second experiment, a latin square design was used to compare four rations during four periods with one lamb fed each ration during each period. The four rations included treated and untreated ear corn silages, dry ear corn and dry ear corn plus ground limestone to equal the amount included in the treated ear corn silage.

RESULTS

Analyses of Various Corn Silages: Analyses of various types of corn silage obtained from conventional silos are presented in Table 1. These results show that high-moisture shelled corn and ear corn undergo a certain amount of fermentation in storage with the production of acetic and lactic acids. The amounts, however, are somewhat lower than in regular whole-plant corn silage. These analyses suggest that, on a dry matter basis, the amounts of acetic and lactic acids produced were directly related to the moisture content of the material ensiled.

Laboratory Experiments: The results of a number of laboratory experiments with whole-plant corn and ground ear corn ensiled in jars with various additives are presented in Table 2. Corn distillers' dried solubles and dicalcium phosphate were added as possible stimulants to fermentation. Calcium carbonate and limestone were added to neutralize acidity, with the possibility that additional acids might be produced. Urea was added as a source of ammonia (4) to serve as a neutralizing material as well as a nitrogen additive to the silage.

The most consistent increase in acid production was brought about by the addition of one percent calcium carbonate or limestone to the

TABLE 1.—Organic Acid Content of Corn Silage Samples Obtained from Conventional Silos.

Type of corn silage	pH	Percent moisture	Percent acid on dry-matter basis	
			Acetic	Lactic
Shelled	4.4	32.2	0.19	1.23
Shelled	4.6	29.1	0.14	0.84
Ground ear	3.7	52.7	0.63	3.22
Chopped ear	4.1	42.0	0.41	2.08
Whole plant	3.7	68.8	0.96	6.26

ensiled material. Apparently, these materials neutralized the acids as produced and the fermentation continued longer or at a faster rate. The dolomitic limestone used in 1958 increased acid production but the increase was not as marked as obtained with calcium carbonate the previous year. However, in 1959 dolomitic limestone appeared to be equal to the high calcium limestone. Urea alone also increased acid production but the increase was not as consistent as calcium carbonate or high calcium limestone. Combinations of urea and limestone appeared to be fully equal to limestone alone. Corn distillers' solubles and dicalcium phosphate increased acid production to a lesser degree than the neutralizing materials.

The first laboratory experiment with ground ear corn showed a definite, direct relationship between moisture content and acid production. Increasing the moisture content of the ensiled material by 10 percent brought about a definite increase in lactic acid either with or without added calcium carbonate.

FEEDING EXPERIMENTS

Four feeding experiments with treated and untreated whole plant corn silage and four with ground ear corn silage were conducted during the period 1958-62. Samples of these silages were collected at intervals during each feeding period. A composite sample was made from several samples of each silage. This composite was analyzed for acteic and lactic acids. Results are presented in Table 3. They are in general agreement with those obtained with silages in glass jars which had been treated with similar materials. The smallest increase in lactic acid production resulted when dolomitic limestone was used as the additive. Results of these studies show a marked increase in organic acid content of corn ensiled with high calcium limestone or a

TABLE 2.—Effect of Certain Additives Upon the Organic Acid Content of Corn Silages Ensiled in Glass Jars.

	pH	Percent moisture	Percent acid on dry-matter basis	
			Acetic	Lactic
Chopped Whole Plant Corn				
September, 1957				
Control	3.7	72.0	1.64	6.48
1% distillers' solubles	3.8	70.8	1.63	7.13
1% calcium carbonate	4.2	73.7	3.57	12.76
1% distillers' solubles and 1% calcium carbonate	4.2	71.2	2.39	12.66
September, 1958				
Control	3.7	70.1	1.35	6.71
1% dolomitic limestone	4.3	67.4	1.60	8.20
2% dolomitic limestone	4.4	68.3	1.74	8.90
1% dolomitic limestone and 5% dried molasses	4.0	66.6	1.55	10.64
September, 1959				
Control	3.8	70.4	1.51	8.33
0.5% limestone	4.0	69.2	1.59	9.72
1.0% limestone	4.2	69.2	1.99	11.05
1.0% dolomitic limestone	4.3	69.9	2.63	11.90
0.5% urea	4.1	69.1	1.92	8.71
1.0% urea	4.4	69.5	1.71	12.00
0.5% limestone and 0.5% urea	4.3	68.9	2.13	12.05
September, 1960				
Control	3.8	70.1	1.51	7.48
1% limestone	4.2	69.8	2.42	11.71
1% urea	4.0	69.2	1.63	8.58
1% dicalcium phosphate	3.8	69.3	1.68	8.51
1% limestone and 0.5% urea	4.5	72.0	3.22	12.99
0.5% limestone and 1.0% urea	4.2	68.9	2.33	11.06
Ground Ear Corn				
February, 1958				
Control	—	32.4	0.28	0.94
1% calcium carbonate	—	34.0	0.41	2.06
Control	—	43.3	0.29	1.81
1 % calcium carbonate	—	43.1	0.37	3.63
February, 1959				
Control	—	35.0	0.21	0.36
0.5% calcium carbonate	—	35.5	0.24	0.66
1 % calcium carbonate	—	36.0	0.38	1.02
5.0% dried molasses	—	34.0	0.19	0.37
September, 1960				
Control	3.8	43.1	0.52	2.88
0.5% limestone	4.0	43.5	0.44	4.64
1.0% limestone	4.0	43.5	0.63	4.63
0.5% limestone and 0.5% urea	4.0	42.3	0.43	4.88
0.5% urea	4.0	43.3	0.51	3.46
1.0% urea	4.0	43.1	0.53	3.34

mixture of equal parts limestone and urea. It was also found that the acid content of ensiled ground ear corn was directly related to its moisture content.

WHOLE PLANT SILAGE (1958-59 Experiment)

Triplicate lots of seven steers were fed each of three rations for an 84 day period. All steers were implanted with 36 mg. of stilbestrol per head at the start of the experiment. Corn silage which had been ensiled with the addition of 1 percent dolomitic limestone was compared to untreated silage and in addition a comparison was made between solvent extracted soybean oil meal and corn gluten feed as protein supplements. Average results of three lots of seven steers fed each ration are presented in Table 4.

There was little difference in average daily gain of steers fed the treated silage with soybean oil meal, untreated silage with soybean oil meal or untreated silage with corn gluten feed. If the limestone included in the treated silage is added to the silage dry matter there is little difference in amount of feed required per 100 pounds of gain. However, if limestone which supplies no energy, is subtracted from the silage dry matter, as has been done in Table 4, there appears to have been slightly less silage required per unit of gain by the steers fed the treated silage. These steers required about 8 percent less silage dry matter per 100 pounds gain than the average of the six lots fed the untreated silage.

When fed at levels to supply similar amounts of protein, there was little difference in value between soybean oil meal and corn gluten feed as protein supplements to a ration containing large amounts of whole plant corn silage.

WHOLE PLANT SILAGE (1959-60 Experiment)

Two identical concrete stave silos were filled on September 8 and September 9, 1959, with well eared corn silage from the same field. One silo was filled in the usual manner without any additions. Approximately 0.5 percent high calcium ground limestone (36.66 percent calcium and 0.29 percent magnesium) and 0.5 percent urea were added to the chopped corn blown into the other silo. These materials were added by sprinkling over the top of the loaded wagons. They became well mixed with the corn as it was dropped off the back of the unloading wagons and blown into the silo.

Choice grade Hereford heifer calves were fed in this experiment. Two groups were fed in a barn without outside lots, two in a narrow open-sided shed with outside lots and two in outside lots without over-

head protection. One lot in each of the three housing conditions was fed the control silage and one the limestone-urea treated silage. One heifer in each of three lots was removed during the experiment because of pregnancy. The ration fed was designed to utilize the silages fully and to produce choice grade slaughter cattle. All lots were fed a specified amount of ground ear corn and full fed silage until they were eating 15 pounds of silage per head daily. They were then fed this amount of silage with ground ear corn full fed. Weights of the heifers and average daily rations consumed are given in Table 5.

TABLE 3.—Effect of Certain Additives Upon the Organic Acid Content of Corn Silages Ensiled in Concrete-Stave Silos.

	pH	Percent moisture	Percent acid on dry-matter basis	
			Acetic	Lactic
WHOLE PLANT CORN				
1958-59				
Control	3.8	69.3	1.24	6.38
1.0% dolomitic limestone	4.3	71.1	2.56	8.13
1959-60				
Control	3.9	68.5	1.44	5.86
0.5% each, limestone and urea	4.5	66.6	1.83	10.42
1960-61				
Control	—	65.5	1.41	7.58
0.5% each, limestone and urea	—	64.5	2.14	10.32
1961-62				
Control	—	67.1	0.98	5.73
0.5% each, limestone and urea	—	65.3	1.25	8.01
1.0% limestone	—	61.5	0.69	8.46
GROUND EAR CORN				
1958-59				
Control	3.8	46.3	0.42	2.26
1.0% dolomitic limestone	4.2	45.8	0.52	3.20
1959-60				
Control	4.1	40.6	0.36	2.07
1.0% limestone and water	4.3	46.4	0.75	4.66
1960-61				
Control	—	43.3	0.45	2.58
0.5% limestone, 0.5% urea and water	—	48.2	0 86	4.17
1961-62				
Control	—	37.2	0.30	1.81
1% limestone and water	—	45.8	0.84	4.11

TABLE 4.—Feed Lot Performance of Steers Fed Limestone Treated Corn Silage or Untreated Silage with Soybean Oil Meal or Corn Gluten Feed as the Protein Supplement.

Silage and supplement	Treated silage soybean meal	Control silage	
		Soybean meal	Gluten feed
Number of steers	21	21	21
Av. wt., November 25, lb.	603	603	607
Av. wt., February 17, lb.	801	800	799
Av. daily gain, 84 days, lb.	2.32	2.35	2.29
Av. daily ration:			
Ground ear corn, lb.	1.5	1.5	—
Corn gluten feed, lb.	—	—	3.0
Soybean oil meal, lb.	1.9	1.9	0.4
Corn silage, lb.	33.8	32.4	32.8
Silage dry matter, lb.	(9.56)	(9.96)	(10.09)
Ground limestone, lb.	0.3	—	—
Hay, lb	1.2	1.2	1.2
Salt, oz.	0.4	0.4	0.4
Minerals, oz.	1.6	1.5	1.1
Feed per cwt. gain, lb.:			
Ground ear corn	65	64	—
Corn gluten feed	—	—	131
Soybean oil meal	80	79	15
Corn silage	1454	1378	1431
Silage dry matter	(410)	(424)	(440)
Ground limestone	15	—	—
Hay	50	49	51
Salt	1.3	1.3	1.7
Minerals	4.3	4.0	3.8

Results of the 224-day feeding experiment, Table 5, indicate a definite improvement in feeding value for the treated silage. In all three comparisons heifers fed the treated silage gained at a faster rate than those fed the control silage. These increased gains averaged 11 percent and proved to be highly significant. When the silage requirement per 100 pounds of gain was converted to an air-dry basis and added to the other feed requirements, cattle fed the treated silage required significantly less feed per unit of gain. There were no real differences in dressing percentages or carcass grades between heifers fed the two silages.

Heifers fed the treated silage ate slightly more corn and silage per head daily. The addition of urea to the treated silage increased its content of crude protein, hence it is possible that the increased feed consumption and rate of gain may have been due to the higher level of crude protein in the treated silage ration. However, this does not seem likely since previous experiments with similar rations (11) had shown

TABLE 5.—Feeding Value of Control and Limestone-Urea Treated Corn Silage for Growing, Fattening Heifers.

Replicate silage designation	Barn		Shed		Outside	
	Control	Treated	Control	Treated	Control	Treated
Number of heifers	13	13	14	14	13	14
Av. wt., Nov. 10, lb.	496	500	500	500	493	500
Av. wt., June 21, lb.	880	923	884	921	867	922
Av. daily gain, 224 days, lb.	1.72	1.89	1.71	1.88	1.67	1.89
Av. daily ration:						
Ground ear corn, lb.	8.2	8.7	8.5	8.7	8 9	8.7
Soybean oil meal, lb.	1.0	1.0	1.0	1.0	1.0	1.0
Corn silage, lb.	13.3	14.1	13.8	14.6	13.9	14.7
Alfalfa hay, lb.	3.0	3.0	3.0	3.0	3.0	3.0
Salt, oz.	0.5	0.4	0.3	0.3	0.6	0.6
Minerals, oz.	0.1	0.2	0.3	0.3	0.4	0.5
Feed per cwt. gain, lb.:						
Ground ear corn	477	459	497	461	537	462
Soybean oil meal	58	53	58	53	60	53
Corn silage	776	745	808	778	833	781
Alfalfa hay	175	160	176	160	181	160
Salt	2	1	1	1	2	2
Minerals	1	1	1	1	2	2
Carcass grade[1]	9.7	9.6	10.1	9.7	9.6	9.4
Dressing percentage	62.1	61.5	60.8	62.4	61.1	61.4

[1]High good, 9; low choice, 10.

no advantage in feeding larger amounts of protein than fed with the untreated silage in this experiment.

WHOLE PLANT SILAGE (1960-61 Experiment)

Two concrete-stave silos were filled on September 14 and September 15, 1960. Approximately 0.5 percent each of high calcium ground limestone and urea were added to the chopped corn in one silo while the other was filled without treatment. The corn used to fill these silos had been severly damaged by hail prior to tasseling and was not of normal composition. It was estimated to have about one-half the normal amount of leaves, was quite mature and contained some dead leaves and stalks. Ears had set and filled well considering the hail damage. Yields of silage were 15.5 tons per acre and similar corn yielded 78 bushels of ear corn per acre.

Six lots of Hereford heifer calves were fed in this experiment. Three levels of soybean oil meal, 0.5 pound, 1.0 pound and 1.5 pounds per head daily, were fed with the treated and untreated silages. The rations of ear corn fed were adjusted so that all lots received the same amounts of concentrates. Final results of this experiment are presented in Table 6.

Although the differences are not large, rate of gain and feed requirements were in favor of the treated silage in all three comparisons. Differences between the two silages were similar with all three levels of soybean meal, however, the difference became slightly larger as the amount of soybean meal fed was reduced. These results are not conclusive but suggest that limestone and urea additions not only increase the acid content of the silage but that the urea may also replace a part of the protein supplement which needs to be fed. Experiments conducted previously at this Station showed the feeding value of corn silage treated with 20 pounds of urea per ton compared very favorably with that of untreated corn silage and soybean oil meal (4).

The gains of all heifers were slightly less than obtained with similar cattle in previous years. The reason for this is not known but it may possibly be related to the hail-damaged corn silage.

TABLE 6.—Feeding Value of Limestone-Urea Treated Silage with Three Levels of Soybean Oil Meal.

	0.5 lb. SBOM		1.0 lb. SBOM		1.5 lb. SBOM	
	Control Silage	Treated Silage	Control Silage	Treated Silage	Control Silage	Treated Silage
LOT	1	2	3	4	5	6
No. in Lot	14	15	14	14	14	14
Av. wt. Nov. 14, lb.	474	476	473	475	482	474
Av. wt. June 13, lb.	814	840	834	857	828	837
Av. daily gain, 211 days, lb.	1.61	1.73	1.71	1.81	1.64	1.72
Av daily ration:						
Ground ear corn, lb.	8.3	8.3	7.9	7.9	7.4	7.3
Soybean oil meal, lb.	.5	.5	1.0	1.0	1.5	1.5
Corn silage, lb.	13.1	13.1	13.8	13.8	14.0	14.3
Mixed hay, lb.	3.0	3.0	3.0	3.0	3.0	3.0
Salt, oz.	.3	.3	.3	.4	.4	.4
Minerals, oz.	.05	.1	.2	.3	.4	.3
Feed per cwt. of gain, lb.:						
Ground ear corn	517	482	464	435	452	427
Soybean oil meal	31	29	58	55	91	87
Corn silage	815	759	809	765	850	832
Mixed hay	186	174	176	166	183	175
Salt	1	1	1	1	2	1.5
Minerals	—	.5	1	1	2	1
Dressing percentage	62.52	61.52	60.66	61.75	60.95	62.32
Carcass grade factor[1]	9.6	9.4	9.4	10.0	9.6	9.6

[1]High good, 9; low choice, 10.

In consideration of the relatively slow gains, all heifers were bled for vitamin A analysis on April 4. One-half of the heifers in each lot were given a capsule containing 750,000 International Units of vitamin A on the same day. These analyses showed an average for all heifers of 26.8 micrograms per 100 ml. of plasma, a level normally considered to be fully adequate. Twenty-eight days later, May 2, the heifers in Lot 5 and Lot 6 were again bled. The untreated heifers then averaged 23.4 micrograms per 100 ml. and the heifers which had received vitamin A averaged 30.2 micrograms per 100 ml. Thus the single large dose of vitamin A had influenced the vitamin A blood levels of the heifers. Although gains for only the last 70 days of the experiment are available, there were no differences in gains of the treated and untreated heifers. During this period, all heifers which had received vitamin A gained 1.67 pounds per head daily and the untreated heifers gained 1.70 pounds.

WHOLE PLANT SILAGE (1961-62 Experiment)

As in the two previous years, one concrete-stave silo was filled with the addition of approximately 0.5 percent each of high calcium limestone and urea and the other without treatment. In the two earlier, long-term experiments which showed a definite advantage for the treated silage, a liberal amount of ground ear corn was fed throughout the feeding period. This 1961-62 experiment was designed to compare the two silages when fed with different amounts of corn. Two lots, 1 and 2, were fed silage without additional corn for the first 126 days and with added corn the last 98 days. Lots 3 and 4 were fed 7.9 pounds of corn per head daily with the silages full fed and Lots 5 and 6 were fed 6 pounds silage per head with ground ear corn full fed throughout the entire 224 day experiment. Hereford heifers were again used as the test animals and it was necessary to remove one heifer from Lot 5 because of pregnancy. Results of this experiment are given in Table 7.

In this experiment, the more silage fed the greater the advantage in favor of the silage which had been treated with limestone and urea. When fed without dry ear corn, heifers fed the treated silage gained 0.25 pounds per head daily more than those fed the untreated silage. This difference was decreased to 0.18 pound for the total experiment after corn had been fed for 98 days. Both differences were statistically significant. Heifers fed the treated silage also required less feed per hundredweight gain, graded higher and yielded a higher percentage of carcass. Differences between the two silages decreased as the amount

TABLE 7.—Feeding Value of Limestone-Urea Treated Corn Silage with Three Levels of Dry Ground Ear Corn.

	First 126 days		Entire 224 day experiment					
	No corn		Limited corn		Medium corn		Limited silage	
	Control	Treated	Control	Treated	Control	Treated	Control	Treated
	1	2	1	2	3	4	5	6
No. heifers	14	15	14	15	14	14	14/13	14
Av. wt. Nov. 14, lb.	467	464	467	464	467	469	474	469
Av. final wt., lb.	663	691	833	870	863	876	895	905
Av. daily gain, lb.	1.55	1.80	1.63	1.81	1.77	1 82	1.90	1.94
Av. daily ration:								
Ground ear corn, lb.	—	—	3.5	3.8	7.9	7.9	12.1	12.9
Soybean oil meal, lb.	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Corn silage, lb.	27.7	28.1	23.1	23.4	14.6	15.0	6.0	6.0
Alfalfa hay, lb.	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Salt, oz.	0.7	0.6	0.6	0.6	0.4	0.5	0.6	0.5
Minerals, oz.	0.6	0.4	0.5	0.3	0.3	0.5	0.5	0.4
Feed per cwt. gain, lb.:								
Ground ear corn	—	—	214	208	447	435	640	662
Soybean meal	64	55	61	55	57	55	53	51
Corn silage	1787	1559	1416	1289	826	824	317	309
Alfalfa hay	193	166	184	166	170	166	159	155
Salt	3	2	2	2	1	2	2	2
Minerals	2	2	2	1	1	2	2	1
Dressing percentage	—	—	59.0	60.0	58.9	59.8	61.6	60.7
Marbling score[1]	—	—	6.1	7.1	6.0	6.5	7.8	7.3
Quality grade[2]	—	—	8.1	9.6	8.5	9.0	10.3	9.8
Yield grade	—	—	2.8	2.9	2.8	3.1	3.1	3.1

[1]Modest, 6; moderate, 7; slightly abundant, 8.
[2]Average good, 8; high good, 9; low choice, 10.

of ear corn fed was increased. When 7.9 pounds of corn was fed per head daily, the results still favored the treated silage but to a lesser degree. When only 6 pounds of silage was fed there was no real difference between the two silages.

GROUND EAR CORN SILAGE (1958-59 Experiment)

Ear corn was picked, ground through a power take-off burr mill and ensiled without treatment or with the addition of 1 percent dolomitic limestone. Other corn picked from the same field at the same time, was artificially dried and ground at the time of feeding. Three lots of 7 steers each were fed each type of corn for 119 days. These were the same steers used in the 1958-59 whole plant silage experiment. At the close of the whole-plant experiment the steers were reallotted on the basis of weight and gain made during the first 84 days. Results of this experiment are presented in Table 8.

There was little difference in rate of gain of steers fed either of the ear corn silages; however, both of these groups gained slightly, but not significantly faster than those fed the dry ear corn and no silage. Even though they gained slightly faster, the steers fed ear corn silage ate, on the dry corn basis, nearly 2 pounds less corn per head, daily. These increased gains and lower consumption resulted in a considerable saving in corn required per 100 pound gain. The steers fed ear corn as silage required 15 percent less corn (dry basis) per unit of gain than those fed the dry corn. It will also be noted that carcass grades of these steers were slightly higher.

Results were much the same whether steers were fed limestone treated or control ear corn silages. If the added limestone is not included, the amount of corn, on the dry basis, required per 100 pounds of gain was slightly less when the treated silage was fed. This difference, however, was less than 3 percent and was not significant. Any increase in feeding value as a result of the small increase in organic acids, 0.15 pound per head daily of acetic and lactic acids combined, would undoubtedly be difficult to measure. It is also possible that force-feeding relatively large amounts of calcium and magnesium in the form of dolomitic limestone may have had a deleterious effect upon the utilization of the ration fed. Colovos *et al.* (7) reported that the addition of pulverized limestone to rations for dairy heifers reduced the digestibility of protein and energy.

GROUND EAR CORN SILAGE (1959-60 Experiment)

Ear corn was picked and artificially dried or ground and ensiled. Experiments conducted in glass jars had shown that the organic acid content of ensiled ear corn could be increased by raising the moisture

TABLE 8.—Average Results of Three Lots of Steers Fed Each Ration of Limestone Treated Ear Corn Silage, Untreated Ear Corn Silage or Dry Ear Corn.

Ration designation	Treated ear corn silage	Control ear corn silage	Dry ear corn
Number of steers	21	21	21
Av. wt., February 24, lb.	814	816	812
Av. wt., July 7 lb.	1102	1102	1084
Av. daily gain, 119 days, lb	2.17	2.15	2.04
Av. daily ration:			
Ear corn silage, lb.	24.0	24.2	—
Ground limestone, lb.	0.2	—	—
Dry ear corn, lb.	(14.6)[1]	(14.7)[1]	16.4
Soybean oil meal, lb	1.5	1.5	1.5
Mixed hay, lb.	2.0	2.0	2.0
Salt, oz.	0.5	0.3	0.4
Minerals, oz.	0 7	0.6	0.5
Feed per cwt. gain, lb.:			
Ear corn silage	1107	1127	—
Ground limestone	11	—	—
Dry ear corn	(668)[1]	(685)[1]	803
Soybean oil meal	69	70	73
Mixed hay	92	93	98
Salt	1	1	1
Minerals	2	2	2
Carcass grade factor[2]	10.6	11.0	9.8
Dressing percentage	62.1	61.2	61.7

[1]Ear corn silage converted to same dry matter basis as dry ear corn, 88.4 %.
[2]High good, 9; low choice, 10; average 11.

content of the corn or by the addition of a neutralizing material. In order to obtain as large a difference as possible in the acid content of the ensiled, treated and untreated corn, 1 percent high calcium limestone and additional water were added to the treated silage. Water was added through a hose at the blower. Analyses of the silage, Table 3, showed that approximately 6 percent water was added by this method. In order to determine dry matter losses during storage and feeding, the total amounts of dry matter stored by the three methods and the amounts of dry matter fed to the cattle were recorded.

Three lots of seven choice grade Hereford steers were fed the limestone-water treated ear-corn silage, three lots the control silage and three lots the dry ear corn. These rations were fed for 224 days. Weights of the cattle, rations consumed and results of this experiment are presented in Table 9.

TABLE 9.—Feeding Value of Limestone-Water Treated and Control Ear Corn Silages and Dry Ear Corn for Growing, Fattening Steers.

Ration designation	Treated ear corn silage			Control ear corn silage			Dry ear corn		
	1	2	3	1	2	3	1	2	3
Number of steers	7	7	7	7	7	7	7	7	7
Av. wt., Dec. 8, lb.	567	564	560	564	565	567	567	570	566
Av. wt., July 19, lb.	1021	1053	1005	993	959	958	972	987	1007
Av. daily gain, 224 days, lb.	2.03	2.18	1.99	1.93	1.76	1.75	1.81	1.86	1.97
Av. daily ration:									
Ear corn silage, lb.	18.9	19.8	18.2	16.6	16.4	16.0	—	—	—
Dry ear corn, lb.[1]	(10.1)	(10.6)	(9.8)	(9.9)	(9.7)	(9.5)	10.7	11.3	11.7
Soybean oil meal, lb.	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Mixed hay, lb.	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Salt, oz.	0.5	0.4	0.6	0.5	0.4	0.3	0.4	0.6	0.4
Minerals, oz.	1.1	1.1	1.1	1.1	1.3	1.1	1.4	1.1	1.4
Feed per cwt. gain, lb.									
Ear corn silage	933	906	914	870	931	915	—	—	—
Dry ear corn[1]	(500)	(486)	(490)	(517)	(553)	(543)	595	605	596
Soybean oil meal	74	69	75	78	85	86	83	81	76
Mixed hay	99	92	101	104	114	114	111	107	102
Salt	2	1	2	2	2	1	1	2	1
Minerals	3	3	3	4	5	4	5	4	4
Carcass grade[2]	11.1	11.4	11.4	11.0	10.6	10.0	10.1	10.4	10.6
Dressing percentage	63.2	63.9	63.7	62.6	61.8	60.4	61.8	62.0	62.6

[1]Converted to dry matter basis.

[2]Low choice, 10; average choice, 11.

Results of this experiment (Table 9) show an increased feeding value from the addition of 1 percent high calcium ground limestone and water to ensiled ground ear-corn. Steers fed the treated silage gained at a faster rate, required less feed per unit of gain, had a higher dressing percentage and graded higher in the carcass than steers fed the untreated silage or dry ear corn. All of these differences were statistically significant.

In this experiment the weights and dry matter content of the total corn harvested and also the total amounts fed to the cattle were recorded. From these data it was possible to calculate the dry matter losses incurred in the different methods of feeding and storage. These losses would include those due to fermentations, spoilage and dust losses during grinding and feeding. These individual losses would be expected to be quite different for the ensiled and dry corn, however, it was possible to determine only the total loss. The total dry matter losses between the amounts stored and the amounts fed to the cattle were 16.8, 16.5 and 12.6 percent for the treated silage, untreated silage and dry ear corn, respectively. With these losses and the amount of ear corn dry matter required to produce a unit of gain (Table 9), it was possible to calculate the amount of beef produced from a given yield of corn. These calculations showed that the net gain in pounds of beef produced from a given weight of harvested corn was 6.4 percent for the untreated silage and 15.8 percent for the treated silage as compared to the dry ground ears.

GROUND EAR CORN SILAGE (1960-61 Experiment)

In this experiment, ear corn was picked with a standard picker, was ground through a burr-mill and ensiled in a concrete-stave silo. Alternate loads of corn were treated by the addition of 0.5 percent high calcium ground limestone, 0.5 percent urea and additional water. The treated silage was separated from the control of untreated silage by a large sheet of plastic in the center of the silo.

Duplicate lots of 7 steers were fed either 0.75 pound or 1.5 pounds soybean oil meal with the treated and untreated silages. All steers were implanted with 24 mg. of stilbestrol at the start of the experiment. Weights of the steers, rations consumed and performance of the cattle are given in Table 10.

Steers fed the treated silage, average of 4 lots, gained 0.11 pound more per head daily than those fed the untreated silage and required about 8 percent less ear corn dry matter per hundredweight of gain. The increased rate of gain did not prove to be statistically significant.

TABLE 10.—Feeding Value of Limestone-Urea-Water Treated Ear Corn Silage with Two Levels of Soybean Oil Meal.

	TREATED SILAGE				CONTROL SILAGE			
	0.75 lb. SBOM		1.5 lb. SBOM		0.75 lb. SBOM		1.5 lb. SBOM	
LOT	8	9	10	11	12	13	14	15
No. in Lot	7	7/6[1]	7	7	7	7	7	7
Av. wt. Nov. 15, lb.	489	483	486	488	491	494	489	487
Av. wt. June 12, lb.	952	929	919	929	883	925	934	903
Av. daily gain, 209 days	2.22	2.10	2.07	2.11	1.88	2.07	2.13	1.99
Av. daily ration:								
Ear corn silage, lb.	18.3	18.7	16.7	17.8	16.6	17.6	16.7	16.2
Ear corn dry matter	(9.5)	(9.7)	(8.7)	(9.2)	(9.4)	(9.9)	(9.5)	(9.2)
Soybean oil meal, lb.	.74	.74	1.48	1.48	.74	.74	1.48	1.48
Mixed hay, lb.	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Salt, oz.	.3	.4	.9	.7	.3	.1	.3	.7
Minerals, oz.	.9	.7	.5	.8	1.0	.8	9	1.0
Feed per cwt. gain, lb.:								
Ear corn silage	824	890	803	842	882	851	783	813
Ear corn dry matter	(428)	(462)	(417)	(437)	(499)	(482)	(443)	(460)
Soybean oil meal	34	35	72	70	40	36	69	74
Mixed hay	90	95	96	95	106	97	93	100
Salt	1	1	3	2	1	.5	1	2
Minerals	2.5	2	2	2	3	2	3	3
Dressing percentage	61.68	63.04	62.19	62 19	60 37	61 39	61.50	61 67
Carcass grade factor[2]	9.7	9.5	8.6	9.1	8.4	9.4	9.1	8.9

[1]One steer removed because of severe chronic pneumonia.

[2]Average good, 8; high good, 9.

However, the increase in feed efficiency was significant at the 5 percent level of probability. The greatest difference between the two silages was when 0.75 pound soybean oil meal was fed per head daily. There was a slight advantage in gain and feed efficiency in favor of the treated silage when 1.5 pounds of soybean meal was fed. These results indicate that additions of urea, limestone and water to ear corn silage not only increase the organic acids produced in the silage but that the added urea may replace a part of the protein supplement which needs to be fed.

GROUND EAR CORN SILAGE (1961-62 Experiment)

High moisture ear corn was ground and ensiled without treatment or with the addition of 1 percent high calcium limestone and additional water. Previous experiments with ensiled ear corn had been conducted without whole plant silage in the ration. Since many feeders feed a combination of the two and since whole plant corn silage contains larger amounts of organic acid than ensiled ear corn this experiment was designed to compare dry, ensiled and ensiled-treated ear corn with and without whole plant silage in the ration. The whole plant silage fed had been treated with one percent high calcium limestone at the time of ensiling. Duplicate lots of seven steers were fed each ration for 210 days at which time the ensiled ear corn was exhausted. All steers were implanted with 30 mg. of stilbestrol per head at the start of the experiment. The results obtained are presented in Table 11.

Result of this experiment are in agreement with those conducted previously. When fed without whole plant silage, steers fed the treated silage gained at a faster rate and required less feed per unit of gain than those fed untreated silage or dry ear corn. When about 12 pounds of limestone treated whole plant silage were included in the daily ration, treatment of the ensiled ear corn did not affect rate of gain but did significantly reduce ear corn dry matter requirements per unit of gain. Thus it appears advantageous to treat ensiled ground ear corn whether or not it is fed with whole plant silage.

The corn plant is low in calcium content. Therefore, the question might be raised whether the benefit from adding limestone to silage might be due merely to the higher calcium content of the ration rather than to its effect upon organic acid production. Information was obtained on this question in the 1961-62 experiment.

Two lots of seven steers each were fed dry ground ear corn with the addition of 1.5 percent high calcium limestone and one lot with the addition of 1.5 percent dolomitic limestone. On a dry matter

TABLE 11.—Feeding Value of Limestone-Water Treated Ear Corn Silage With and Without Whole Plant Silage.

Ear Corn	No whole plant silage			With whole plant silage		
	Dry	Ensiled	Ensiled treated	Dry	Ensiled	Ensiled treated
No. steers	14	14/13[1]	14	14/13[2]	14	14
Av. wt. Nov. 21, lb.	482	489	477	480	482	478
Av. wt. June 19, lb.	956	972	1012	998	976	991
Av. daily gain, 210 days, lb.	2.26	2.28	2.54	2.44	2.36	2.44
Av daily ration:						
Ground ear corn, lb.	12.2	17.2	19.8	10.1	12.0	13.6
Ear corn dry matter, lb	10.8	10.8	10.7	8.9	7.5	7.4
Corn silage, lb	—	—	—	12.0	11.8	11.8
Soybean meal, lb.	1.5	1.5	1.5	1.5	1.5	1.5
Mixed hay, lb.	2.0	2.0	2.0	2.0	2.0	2.0
Salt, oz.	0.6	0.3	0.5	0.4	0.4	0.6
Minerals, oz.	0.9	0.9	0.8	0.8	1.1	1.2
Feed per cwt. gain, lb.:						
Ground ear corn	543	752	778	415	512	554
Ear corn dry matter	480	472	422	367	322	300
Corn silage	—	—	—	493	501	484
Soybean meal	66	66	59	62	64	62
Mixed hay	89	88	79	82	85	82
Salt	1	1	2	1	1	1
Minerals	2	2	2	2	3	3
Dressing percentage	61.1	61.4	62.8	62.1	62.8	61.6
Marbling score[3]	4.6	4.9	4.2	4.4	4.4	4.6
Quality grade[4]	8.7	9.0	8.2	8.2	8.6	8.6
Yield grade	2.8	2.9	3.0	3.1	3.0	2.8

[1]One steer foundered and was removed from the experiment.
[2]One steer died from mucosal disease.
[3]Slight, 4; small, 5.
[4]Average good, 8; high good, 9.

basis, this amount of limestone was approximately equal to the one percent added to the ensiled ear corn. Results of these comparisons are presented in Table 12. These comparisons were conducted at the same time and with similar cattle so that the results are directly comparable to those presented in Table 11.

There were no real differences in performance of steers fed dry ground ear corn with or without added limestone. Steers fed high calcium limestone gained slightly faster and those fed dolomitic limestone slightly slower than steers fed dry ear corn without added limestone. None of these differences are significant.

DIGESTION EXPERIMENTS

Digestion experiments were conducted with wether lambs to study the effect of added limestone upon the digestibility of ration consti-

TABLE 12.—Feeding Value of Dry, Ground Ear Corn With and Without Added Limestone.

LOT	High Ca limestone 1 and 2	Dolomitic limestone 3	Control 4 and 5
No. steers	14/13[1]	7	14
Av. wt. Nov. 21, lb.	481	480	482
Av. wt. June 19, lb.	980	939	956
Av. daily gain, 210 days, lb	2.32	2.19	2.26
Av. daily ration:			
Ground ear corn, lb.	12.4	12.2	12.2
Soybean meal, lb.	1.5	1.5	1.5
Mixed hay, lb.	2.0	2.0	2.0
Salt, oz.	0.3	0.4	0.6
Minerals, oz.	0.8	1.1	0.9
Feed per cwt. gain, lb.			
Ground ear corn	538	559	543
Soybean meal	64	68	66
Mixed hay	86	91	89
Salt	1	1	1
Minerals	2	3	2
Dressing percentage	60.3	61.7	61.1
Marbling score[2]	4.5	4.7	4.6
Quality grade[3]	8.6	8.6	8.7
Yield grade	2.8	2.9	2.8

[1]One steer foundered and was removed from the experiment.
[2]Slight, 4; small, 5.
[3]Average good, 8; high good, 9.

tuents. The feeds used were the same as those fed to the cattle in the 1958-59 whole plant and ear corn experiments. Results of these experiments are given in Table 13.

In the first digestion experiment, one lamb was erratic in amount of feed eaten and hence the results obtained with this lamb are not included in the results presented. There were no significant differences in digestibility of organic matter, cellulose, crude fiber, protein or ether extract between rations which included limestone treated or untreated whole-plant corn silage. There was no indication that the one percent added limestone had any depressing effect upon the digestibility of these ration components.

Statistical analysis of results obtained in the second experiment indicated that the digestibility of ether extract in the dry ear corn ration with added limestone was significantly lower than in the three other rations fed. None of the other differences between rations were statistically significant. Digestion coefficients of the ration which

TABLE 13.—Effect of Dolomitic Limestone Upon Digestibility of Corn Silages and Dry Ear Corn.

Ration	No. of animals	Digestibility of Organic matter, percent	Cellulose, percent	Crude fiber, percent	Protein, percent	Ether extract, percent
Experiment I, Whole plant corn silage:						
Control	3	67.1	40.5	37 9	59.8	64.9
Silage plus 1 percent limestone	3	67.4	42.6	41 0	60.0	67 5
Experiment II, Ear corn·						
Dry ear corn	4	77.9	30.0	29.9	67.1	85 9
Dry ear corn plus limestone	4	77.8	31.8	29.1	66.9	78.6*
Ear corn silage	4	78 9	32.4	31 2	60.9	86.5
Ear corn silage plus 1 percent limestone	4	81.1	38.7	38.2	67.7	88.9

*Significantly lower than other three rations fed (P .05).

included ear corn silage with one percent limestone were fully as high as obtained with the rations which did not include dolomitic limestone. Results of these experiments indicate that the addition of one percent pulverized dolomitic limestone to whole-plant or ground ear corn at the time of ensiling did not decrease their digestibility.

DISCUSSION

Analyses of high moisture, ensiled shelled and ground ear corn samples showed these feeds to contain organic acids similar to those present in whole plant corn silage but in relatively smaller amounts. Feeding experiments (5, 10, 12) suggested that the high feeding value of these silages might be related to their content of organic acids. These fermentation products are similar to those produced in the rumen of cattle fed fattening rations. The relative efficiency of these fermentations as they occur in the silo or in the rumen is not known. If the efficiency of conversion to organic acids is greater in the ensiling process than in the rumen, then this conversion prior to ingestion by the animal would increase the overall efficiency of conversion of corn dry matter to the end products of rumen fermentation.

Numerous experiments with silages made in glass jars and in conventional silos have shown that the addition of a neutralizing material at the time of ensiling markedly increased the organic acid content of

the resultant silages. Calcium carbonate or pulverized high calcium limestone alone consistenely brought about this increase. Although no direct comparisons in feeding value were made between dolomitic and high calcium limestone, results suggest that the high calcium is superior to the dolomitic limestone, possibly because of the high magnesium content of the dolomite. Urea alone was not as consistent in increasing organic acid content as calcium carbonate or high calcium limestone. However, mixtures of limestone and urea were fully equal to limestone alone.

Eight feeding experiments, involing a total of 598 cattle, were conducted to determine whether or not the treatment of corn silages to increase their organic acid content would increase their feeding value. In some experiments, cattle fed the treated silages gained at a faster rate, graded higher and yielded a higher percentage of carcass. In other experiments there were no significant differences in these traits between cattle fed the treated and untreated silages. However, in all eight experiments, treatment of the silage consistently reduced feed requirements per unit of gain. These benefits were obtained by adding one percent limestone, one percent of a mixture equal parts limestone and urea, or, in the case of ground ear corn, these additives in combination with additional water to the corn at the time of ensiling.

The organic acid content of high moisture ear corn was found to be directly related to the moisture content of the ensiled material. Thus, it would be most desirable to grind and store ears when they contain a relatively high amount of moisture. However, nutrient storage in the corn plant occurs at a rapid rate while the ears are filling. Hence, they should not be picked before maturity or there will be a reduction in yield of nutrients. It would be more profitable to allow the corn to mature and then add water at the time of grinding and ensiling.

Limestone or a mixture of equal parts limestone and urea appeared to be of equal value in stimulating organic acid production in the silo. For this purpose, there would be little choice between them. However, urea does supply nitrogen, a source of crude protein for ruminants, and could replace a part of the protein supplement needed with a silage ration. On the other hand, limestone is lower in price and more readily available.

It is possible that there may be an upper limit to the amount of organic acids which can be utilized efficiently by fattening cattle. However, if so, it was apparently not reached in these experiments since steers fed a combination of limestone-water treated ear corn silage

and limestone treated whole plant silage gained more efficiently than those fed untreated silage or no whole plant silage.

Treatment of corn silages with neutralizing materials increased their content of organic acids and increased their feeding value. This does not prove that the higher feeding values were necessarily due to the increased content of organic acids. The benefits realized may have been due to some other constituents or changes in the silages. However, it is indicated that the increased feeding values were not due to the additives themselves since no benefit was realized from the addition of equivalent amounts of limestone to dry ear corn. Also, in previous experiments (4), corn silage treated with urea improved the performance of steers more than feeding the same amount of urea mixed with dry ground corn. In consideration of the feed replacement value of lactic acid (10, 12) the higher acid content of the treated silages appears to be a logical explanation of their higher feeding value.

As mentioned previously, the corn plant is low in calcium content and the addition of limestone to silage will correct this deficiency. The pH of the treated silages was slightly higher than the untreated which means the acidity was lower and the silage would be less likely to attack the walls of the silo. The calcium of limestone and ammonia of urea combine with the acid to produce salts of the organic acids. It was also noted that there was less molding and spoilage of the treated silage. This was especially true of the ear corn silages in warm weather.

SUMMARY

Samples of high moisture shelled and ground ear corn stored in conventional silos were found to contain acetic and lactic acids. These are the same as the predominant acids found in whole plant silage and are similar to those produced in the rumen of cattle fed fattening rations.

Laboratory experiments with whole plant and ground ear corn ensiled in glass jars showed that the acetic and lactic acid contents of the resultant silages were directly related to the moisture content of the material ensiled. Additions of one percent of a neutralizing material such as calcium carbonate, high calcium limestone or a mixture of limestone and urea markedly increased acid production in the silo.

Four feeding experiments with ensiled ground ear corn and four with whole plant silage, involving a total of 598 cattle, were conducted to compare the feeding value of treated and untreated silages. All

eight experiments showed an increase in feed efficiency as a result of adding one percent limestone, one percent of a mixture of limestone and urea or, in the case of ground ear corn, these additives in combination with additional water to the corn at the time of ensiling. In four of the experiments, cattle fed the treated silages also gained at a significantly faster rate. The exact reason for the improved performance is not known, however, it is believed to be due to the higher organic acid content of the treated silages.

Digestion experiments with wether lambs showed that the addition of limestone did not decrease the digestibility of organic matter, cellulose, crude fiber, protein or ether extract of the whole plant or ground ear corn silages.

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