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Silage Investigations

Normal Temperatures and Some Factors Influencing the Quality of Silage

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Normal Temperatures and Some Factors, Influencing the Quality of Silage

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The sharp advance in the price of feed in recent years has greatly stimulated interest in the silo and its use. It has been estimated that 10,000 silos are now in use in Missouri. Although the silo is not new, the increased use recently has made a demand for information on many questions connected with its use which is not as yet available. As a result of this condition, the Missouri Experiment Station began a series of investigations on the subject in the fall of 1913. At the present time, such portions of the results will be reported as appear reasonably complete. Other questions are still under investigation and the results will be reported at a late date. The data included at this time concern four points: (1) normal temperature of silage and factors influencing it, (2) the relation of quality to temperature during fermentation, (3) the relation of the material used in constructing the silo to the composition and quality of silage, and (4) the accuracy of small silos for experimental purposes.

Normal temperature of silage.—Many questions concerning the keeping qualities of silage and the use of the silo are connected in one way or another with the question of the temperature of the silage when in the silo.

The data already available on this point are hardly complete enough to make it possible to explain some of the irregularities and variations in temperature which have been reported. Some of the data reported were taken from work with a square silo before the present round type came into use, and it seems probable that the conditions necessary for good silage were not understood then as well as they are at the present.

[1] The planning of this investigation and the preparation of the data for publication was done by C. H. Eckles. O. I. Oshel is responsible for the data during the season of 1914-15, and D. M. Magruder for that taken during 1913-14. All chemical analyses given in this publication except the tests for acidity and dry matter were made by the Department of Agricultural Chemistry under the direction of Dr. P. F. Trowbridge.

It seemed advisable to take up this question, among others, with the hope of obtaining more definite information under conditions better controlled. The specific questions it was hoped the data taken would answer are: (1) What are the limits of variation in the temperature of the silage mass from the time it is put into the silo until it is taken out? (2) What are the causes of the variations in temperature found? (3) Does the material used in the construction of the silo exert any influence upon the temperature of the silage? and (4) What relation does the temperature of the silage bear to the quality of the silage produced?

Literature.—The review of previous investigations which follows includes all which concern the subject matter of this bulletin. Attention should be called to the fact that temperatures found by some of the investigators in small experimental silos are not a reliable guide as to what is found in large silos as used under practical conditions.

Short, of the Wisconsin Experiment Station,[2] in the fall of 1889, using small square silos and taking the temperature with maximum thermometers in pipes placed in the silos at filling time, reports that on the second day after filling the temperature registered was 123° F. It continued to rise for a week when the maximum was reached at 163° F and then slowly fell to 105° on November 13. Good silage was produced with an acid content of 1.26 per cent calculated as acetic acid.

Cook, of the Vermont Experiment Station,[3] reports a temperature of 80° F. on the second day after filling, then a gradual decline to 60° F. within 21 days when the silo was opened. The silos were circular wooden tanks, three feet high and two feet in diameter.

Lamson, of the New Hampshire Experiment Station,[4] took temperatures with an electrical apparatus in two square silos 13 x 14 feet and 30 feet deep. Two electrodes (1 and 2) were placed in one silo, and three electrodes (3, 4, and 5) were placed in the other at different depths during the filling of the silos. The maximum temperatures, the time after installation, and the temperatures at the time of uncovering the electrodes are shown in Table 1.

[2] Short, F. G. Varieties of Corn, Changes in the Silo, and Feeding Rations. Notes on Ensilage, Wis. Exp. Sta. Bull. 19:16-28. 1889.

[3] Cooke, W. W. Fodder Crops. Ver. Exp. Sta. Ann. Rept. 1889:96.

[4] Lamson, H. H. Silo Temperatures Taken by Electricity. N. H. Exp. Sta. Ann. Rept. Bull. 79:29-33. 1900.

TABLE 1.—TEMPERATURE READINGS

Electrode number	Maximum temperature	Days after installation	Temperature when uncovered	Date uncovered
	Degrees F.		Degrees F.	
1	118	2	71	February 17
2	105	26	85	January 14
3	100	3	70	February 17
4	103	43	98	February 17
5	127	5	97	January 14

Electrode 5 was probably so close to the surface as to be influenced by external factors.

According to Babcock and Russell of the Wisconsin Experiment Station,[5] the large amount of heat developed in silage may, under normal conditions, be attributed to the intromolecular respiration of the ensiled material. They also demonstrated, by using vessels ranging in size from a pint to several gallons and kept under conditions of controlled temperature, that just as good silage can be made in small containers at room temperature (60° F. to 70°) as in large silos where the temperature is much higher, "showing that the accumulation of heat which naturally occurs in a silo when large masses of fodder are ensiled, is not at all essential for the production of good silage."

The work on temperature changes in the silo was continued by Babcock and Russell,[6] during the next year with much the same results. Galvanized iron receptacles one and one-half feet in diameter and four feet high were used as silos. These cans were filled with field corn of an average state of maturity, and hermetically sealed. The maximum temperature was recorded on the first day. There was a gradual decline to the temperature of the room on about the twelfth day, and from this time on, the temperature of the cans fluctuated with the temperature of the room. The cans were opened on the twenty-fifth day. There was no spoiled silage and it appeared normal in every way. The silos were then left uncovered to note the effect of the bacterial and mould development on the temperature. There was no striking rise until the third day. The thermometer was placed about four inches below the surface, and indicated that the rise in temperature was rapid after this time and reached the maximum of 122° F. in about ten days. After this point, the temperature again declined but did not go as low as the room temperature.

[5] Babcock, S. M., and Russell, H. L. Causes Operative in the Formation of Silage (second paper). Wis. Exp. Sta. Ann. Rept. 1901:177-184.

[6] Same as 5.

Pernot[7] reports temperatures taken at the centers of three experimental silos, 12 x 5 x 5 feet as shown in Table 2.

TABLE 2.—TEMPERATURE READINGS TAKEN AT CENTERS OF SILOS

Silo	Maximum temperature	Days after filling	30 days after filling
	Degrees F.		Degrees F.
1	76	13	64
2	80	7	62
3	66	5	62

Temperature observations from large silos and covering a period of five years were reported by the Storrs Experiment Station.[8] The highest temperature, 126° F. was found at the surface where the silage was exposed to the air. The highest temperature found within the silage mass did not exceed 86° F. During the filling of the silo in 1910, five maximum thermometers were buried in the silage. All were placed about half way between the center and the wall of the silo, with about twenty tons of silage between each thermometer, and about forty tons above the first thermometer. At the time this work was reported, only two thermometers had been recovered and they registered 80.6° F. and 80.4° F. respectively. The authors report the best temperature for silage formation to be from 75° F. to 85° F. They state that a temperature above 100° F. means silage destruction, and below 65° F. during fermentation results in the production of silage of poor quality.

Neidig, of the Iowa Experiment Station,[9] reports temperatures in a wooden stave, a hollow tile, and a concrete silo for a period from the middle of September to the second week in October. Temperatures were taken at the center, two feet from the center, two feet from the wall, and at the wall of each silo. The readings were taken with an electrical apparatus of a type similar to the one used by the Missouri Experiment Station in the investigation reported in this bulletin. All three silos showed about the same characteristics with reference to temperature where the thermometers were not affected by outside influence. The time during which the temperatures were taken was short and the data merely shows that when silage is put up right no

[7] Withycombe, J. The Silo and Silage. Ore. Exp. Sta. Ann. Rept. 1902:68-69.

[8] Esten, W. M., and Mason, C. J. Silage Fermentation. Storrs Exp. Sta. Bull. 70:22-30. 1912.

[9] Neidig, R. E. Chemical Changes during Silage Fermentation. Ia. Exp. Sta. Res. Bull. 16. 1914.

high temperatures are obtained during the period of silage formation. The maximum in this case was 91° F. in both the concrete (18 days after filling) and the hollow tile silo (9 days after filling), and 86° F. in the stave silo (21 days after filling.)

EXPERIMENTAL WORK

Description of silos and methods used.—The silos used in these investigations are situated in or near Columbia, Missouri, and are referred to in experimental data as: south concrete silo, north concrete silo, iron silo, Miller's stave silo, Reid's stave silo, Conley's stave silo, Gurler silo, tile silo, experimental silos, experimental cans.

The south and north concrete silos are situated at the dairy barn on the University farm. They are of the monolithic type, with concrete floors, and are 33 feet high, 16 feet in diameter, and set 5 feet in the ground.

The iron silo, situated at the Experiment Station cattle feeding sheds, is 26 feet high, 12 feet in diameter, and sets about 4.5 feet in the ground. The part above ground is constructed of sections of sheet iron two and one-half feet in width riveted together.

The tile silo is situated on a farm southeast of Columbia and is 42 feet high, 14 feet in diameter, and sets 2 feet in the ground. It is made of glazed hollow tile blocks laid in cement.

All of the stave silos are of typical construction. Miller's stave silo is 37 feet high, 16 feet in diameter, and sets five feet in the ground. Reid's stave silo, situated on a farm east of Columbia, is 32 feet high, 16 feet in diameter, and sets 4 feet in the ground. Conley's stave silo, situated on a farm west of Columbia, is 30 feet high, and 18 feet in diameter. The Gurler silo is on a farm near Columbia and is 30 feet high and 14 feet in diameter. It has been used several years and the plastering has cracked in places.

The experimental silos used are circular water tanks six feet high and three feet in diameter and are built of two inch cypress. Each has a water tight bottom, and tops were made which would fit loosely inside the silo as the silage settled. They were placed in the dairy barn for protection from the cold. The method of using these silos is explained in detail in another paragraph.

Temperature observations.—Temperature readings were taken by means of electrical resistance thermometers.[10] This apparatus consists of a portable indicator and resistance thermometers. The readings are taken by passing a current of electricity thru wires attached to the

[10] Made by Leeds and Northrup Company, Philadelphia, Pennsylvania.

resistance thermometers which may be at any distance from the indicator. In order to protect the resistance thermometers and wires, they were placed in half-inch iron pipe. In this way, the wires were carried to the surface of the silage so that readings could be taken. By this means, it was possible to take the temperature at any time at any point where a resistance thermometer had been placed. In placing the thermometers in the silo, a vertical pipe was placed against the wall extending from the top of the silo to the desired depth. From an elbow at the lower end of this pipe, a similar pipe extended to the center of the silo. One thermometer was placed at the lower end of the perpendicular pipe to enable the temperature to be taken inside and against the wall, and one at the end of the horizontal pipe in the center of the silo in order that the temperature might be taken at this point. These pipes were placed in the silo at the time of filling and allowed to settle with the silage. When a reading was desired, the wires from the thermometer were connected with the indicator box and, on passing the current through the apparatus, the temperature could be read directly in degrees Fahrenheit on the indicator scale.

The readings were taken daily for the first few days in the silos which were located close enough at hand to make this practical. The interval between readings was gradually lengthened as the result indicated no advantage would follow more frequent readings. The atmosphere temperatures given were supplied by the local U. S. Weather Bureau office. Those given to compare with the readings taken in the silos during 1913-1914 represent the temperature at the same hour the reading was made in the silo. The atmosphere temperatures given in the table for 1914-1915 represent the mean for the day during which the reading was made.

Acidity.—The tests for acidity were made as follows: one hundred gram samples of the fresh silage chopped fine, were washed with successive portions of distilled water until the washings showed no more acidity when titrated with tenth-normal alkali solution. Four or five washings were usually required. Intervals of 24 hours were allowed between washings. When the solutions were highly colored, they were decolorized by washing over animal charcoal. An average molecular weight of 80 was assumed in calculating the acidity percentage, following the precedent of Esten and Mason.

TABLE 3.—TEMPERATURE READINGS

Date	At wall[1]	Two feet from wall	Three feet from center	At center[2]	Mean air temperature
	Degrees F.	Degrees F.	Degrees F.	Degrees F.	Degrees F.
South Concrete Silo[3]					
September 7, 1914	89	90	96	93	74
September 8...	80	91	93	93	66
September 9...	78	89	93	92	64
September 14...	82	90	95	92	78
September 15...	80	91	94	94	72
September 18...	81	89	94	94	72
September 19...	84	90	94	94	75
September 23...	76	89	94	93	57
October 2...	76	86	92	94	66
October 9...	73	84	91	93	67
October 23...	81	79	89	91	65
November 14...	57	73	84	88	59
December 12...	37	62	77	84	26
January 1, 1915	31	50	52	79	36
January 15...	39	49	52	74	50
North Concrete Silo[4]					
September 24, 1914	68	..	..	65	62
September 26...	72	..	..	72	60
September 28...	72	..	..	74	64
September 29...	76	..	..	76	64
October 1...	78	..	..	78	68
October 2...	77	..	..	77	66
October 5...	77	..	..	78	71
October 9...	73	..	..	78	67
October 23...	71	..	..	79	65
November 14...	61	..	..	79	59
December 12...	39	..	..	78	26
January 1, 1915	34	..	..	74	36
January 15...	65	..	..	71	50
January 29...	..	..	..	69	16
February 2...	47	..	..	67	28
February 23...	67	..	..	63	40
March 13...	50	..	..	60	40
March 26...	55	..	..	58	34
April 10...	58	..	..	58	60
April 19...	73	..	..	61	70
Iron Silo[5]					
September 4, 1915	98	..	..	97	71
September 5...	98	..	..	99	79
September 7...	78	..	..	99	74
September 8...	85	..	..	100	66
September 9...	71	..	..	102	64
September 15...	84	..	..	101	72
September 18...	95	..	..	100	72

[1] The temperature in the half-inch iron pipe in direct contact with the wall.
[2] The center of the silo horizontally, and sufficiently far from either the top or bottom of the silo to avoid being influenced from these sources.
[3] Filled September 2-5, 1914; readings taken 17 feet below top of silage.
[4] Filled September 22-23, 1914; readings taken 7½ feet below top of silage.
[5] Filled August 29-31, 1914; readings taken approximately 16 feet below top of silage.

TABLE 3.—TEMPERATURE READINGS—Concluded

Date	At wall[1]	Two feet from center	Three feet from center	At center[2]	Mean air tempera-tnre
	Degrees F.	Degrees F.	Degrees F.	Degrees F.	Degrees F.
Iron Silo—Cont.					
September 19, 1915	98	..	..	101	75
September 23...	86	..	..	100	57
October 2...	94	..	..	101	66
October 9...	72	..	..	97	67
October 23...	70	..	..	93	65
November 14...	61	..	..	85	59
December 12...	32	..	..	76	26
January 1, 1915	53	..	..	68	36
January 15...	74	..	..	61	50
January 29...	..	..	..	59	16
February 2...	42	..	..	58	28
February 23...	44	..	..	52	40
March 13...	60	..	..	50	40
March 26...	..	..	..	48	34
April 10...	..	..	..	48	60
April 19...	95	..	..	48	70
Tile Silo[6]					
September 15, 1914	79	..	..	92	72
October 20...	64	..	..	89	64
December 8...	49	..	..	81	38
January 9, 1915	39	..	..	77	36
January 23...	33	..	..	74	3
February 8...	24	..	..	73	28
February 16...	30	..	..	71	37
March 2...	44	..	..	68	35
March 16...	47	..	..	70	39
March 30...	50	..	..	65	37
April 13...	71	..	..	65	50
Miller's Stave Silo[7]					
September 29, 1914	86	95	96[8]	96	64
October 24...	71	82	91	91	54
December 12...	43	63	80	80	26
January 16, 1915	52	60	71	72	40
January 26...	34	56	84	72	21
February 5...	42	55	68	69	30
February 18...	50	60	69	68	45
January 25...	43	55	67	68	34
March 9...	41	60	64	66	32
March 18...	43	57	64	66	36
March 25...	37	56	63	64	41
April 6...	58	59	62	62	64
April 15...	57	62	62	58	64

[6] Filled September 2-4, 1914; readings taken approximately 22 feet below top of silage.
[7] Filled September 12-15, 1914; readings taken approximately 20 feet below top of silage.
[8] For this silo, readings were taken 3½ feet from center, instead of 3 feet.

TABLE 4.—TEMPERATURE READINGS[1]

Date	At wall	At center	Mean air temperature
	Degrees F.	Degrees F.	Degrees F.
Reid's Stave Silo[2]			
September 9, 1914	..	71	64
January 16, 1915	..	68	40
January 26	..	67	21
February 5	..	66	30
Gurler Silo[3]			
September 16, 1914	94	114	77
September 27	87	108	64
October 18	79	..	60
November 22	70	..	38
North Concrete Silo[4]			
September 3, 1913	92	90	100
September 4	99	95	100
September 5	97	97	81
September 6	96	99	79
September 7	92	100	74
September 8	92	101	90
September 10	88	101	89
September 12	82	102	64
September 13	79	102	71
September 14	76	102	69
September 27	66	102	68
September 29	74	103	77
October 3	76	103	78
October 4	76	102	72
October 7	78	102	75
October 12	76	101	76
October 17	66	101	47
October 31	47	98	29
November 7	59	95	55
November 17	47	94	42
December 2	59	88	61
December 14	50	85	45
January 6, 1914	34	77	38
January 31	40	70	37
February 9	27	68	25
February 22	36	63	36
March 10	42	59	40
March 13	38	58	46
March 16	53	60	48
March 25	50	59	60
March 31	56	58	57
April 11	48	53	..
April 17	66	54	..
South Concrete Silo[5]			
September 6, 1913	101	99	86
September 7	98	102	74

[1] On account of accidents to the wires, only a few readings were obtained in Reid's stave silo and in the Gurler silo.
[2] Filled August 29 to September 1, 1914.
[3] Filled August 26, 1914.
[4] Filled September 1-3, 1913; readings taken 23 feet from top of silage.
[5] Filled September 2, 5, 9, 10, 1913; readings taken 22 feet below top of silage.

TABLE 4.—TEMPERATURE READINGS[1]—Continued

Date	At wall	At center[3]	Mean air temperature
	Degrees F.	Degrees F.	Degrees F.
South Concrete Silo—Continued			
September 8, 1913	97	103	90
September 12		104	64
September 29	78	104	77
October 3	81	104	78
October 4	81	104	72
October 7	85	104	75
October 12	81	104	76
October 17	72	104	47
October 31	55	100	29
November 7	66	98	55
November 17	54	96	42
Iron Silo[6]			
August 30, 1913	80	78	91
August 31	99	76	102
September 1	97	79	101
September 2	99	80	100
September 3	81	81	76
September 4	86	82	93
September 5	87	82	81
September 6	83	84	79
September 7	79	85	74
September 8	94	85	90
September 10	87	86	89
September 12	71	86	64
September 13	81	88	71
September 14	68	89	69
September 29	88	97	77
October 3	76	93	78
October 4	77	93	72
October 7	88	93	75
October 12	89	92	76
October 17	59	92	47
October 31	41	90	29
November 17	48	85	42
December 2	64	82	61
December 14	54	80	45
Conley's Stave Silo[7]			
September 4, 1913	109	104	99
September 5	106	107	98
September 7	102	110	82
September 9	100	110	72
September 12	94	110	70
September 29	78	110	68
October 7	81	110	75
October 17	74	109	47
November 7	63	104	55
November 28	64	99	61

[6] Filled August 28-29, 1913; readings taken 8 feet below top of silage.
[7] Filled September 1, 1913; readings taken 18 feet below top of silage.

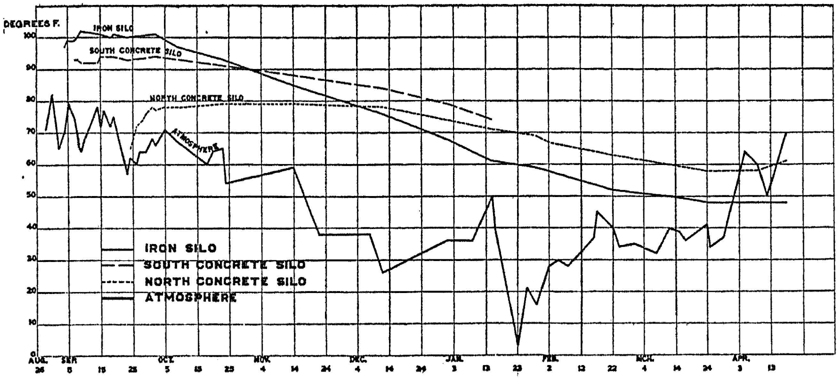

FIG. 1.—THE TEMPERATURE AT THE CENTER OF IRON AND CONCRETE SILOS

The temperature reading at the center of these silos at filling was between 90° and 100° F. It declined gradually from the time of filling and the material used in the construction of the silo showed very little influence on this temperature. Based on Table 3.

TABLE 4.—TEMPERATURE READINGS[1]—Concluded

Date	At wall	At center[2]	Mean air temperature
	Degrees F.	Degrees F.	Degrees F.
Gurler Silo[8]			
September 6, 1913	102	112	90
September 7	104	111	91
September 10	99	109	90
October 12	89	111	76
October 25	79	110	68
October 31	68	110	40

[8] Filled September 4-5, 1913; readings taken 18 feet below top of silage.

It will be noted in Table 3 that in the south concrete silo and in Miller's wooden stave silo, readings were taken at four points, just inside the wall, 2 feet from the wall, 3 feet from the center, and at the center. The object in doing this was to give further data as to the variation from wall to center, and the process of giving off heat during the cold weather. It will be observed that in all silos where readings were made at close intervals following the filling, the temperatures of the silage mass rose slightly during the first few days, then gradually declined. This is illustrated in the cases of the north concrete silo and the iron silo in Table 3, and the north concrete, south concrete, iron, and Conley's stave silos in Table 4. The readings in the other silos were not begun soon enough to make it possible to observe this change.

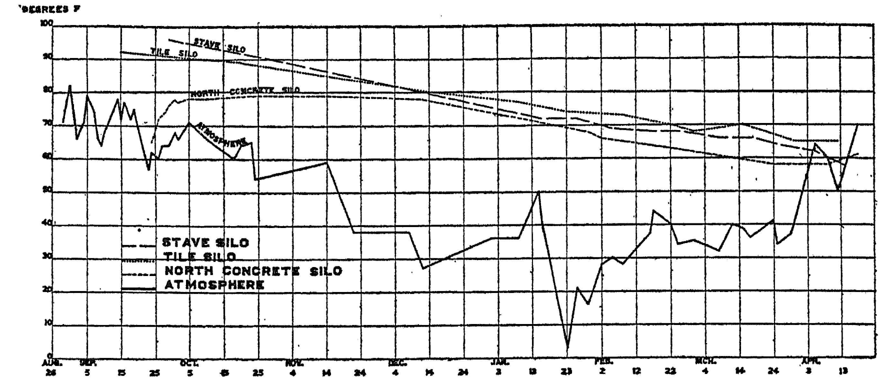

FIG. 2.—THE TEMPERATURE AT THE CENTER OF STAVE, TILE, AND CONCRETE SILOS

The temperature readings in these silos start at practically the same point and show the same gradual decline, as illustrated by Figure 1. There is no indication that the material used in building the silo exerts any influence upon the temperature of the silage at the center of the silo. Based on Table 3.

The highest temperature is generally reached about ten days after filling is completed. The amount of the rise in temperature varies in different silos. It may be as little as two or three or as high as fifteen degrees. After the high point is reached, the change in temperature proceeds very slowly. It is difficult to say whether or not heat is developed continuously while the silage remains in the silo. The indications are that if heat is developed after the first few weeks, it is very small in amount.

After the highest point in temperature is reached, there is a gradual decline such as might reasonably be expected to result from the gradual cooling of the silage mass by radiation of the heat in the atmosphere. This gradual decline is illustrated in Figures 1 and 2. Starting as a rule between 90° and 100° F. in this locality, the temperature at the center of the silo has decreased to about 80° by December 1. During the month of March, the temperature in the center of the silo reaches the lowest point for the year and ranges near 60° F. If the silage remains in the silo until the mean temperature of the air is higher than that of the silage, the temperature of the mass begins to rise slowly.

FACTORS AFFECTING TEMPERATURE OF SILAGE

Temperature of air at filling.—It is evident this factor has considerable influence upon the temperature of the silage during the first few weeks after filling. This influence is readily seen in the data given

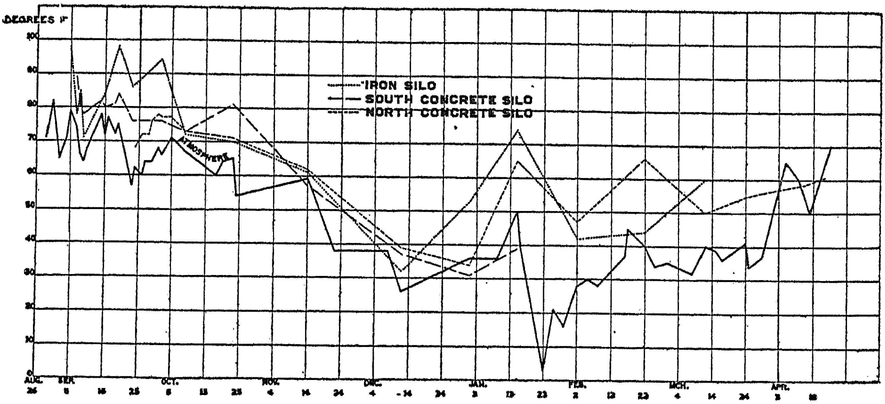

FIG. 3.—THE TEMPERATURE AT THE WALL OF IRON AND CONCRETE SILOS

The temperature of the silage next to the wall followed that of the air rather closely in all three silos. Based on Table 3.

in the tables. Table 3 gives the temperature in the north concrete silo filled when the atmosphere was low. No water was added to this corn. The corn had a temperature of about 65° when put in and raised to a maximum of 79°. Table 4 gives the results in a silo (the north concrete) filled when the atmosphere was at a temperature close to 100° F. during the day. Some water was added on account of this corn being too dry. This accounts for the temperature reading being ten degrees below that of the atmosphere. The high temperatures in Conley's stave silo and the Gurler silo as shown in Table 4 were due to a combination of high temperature at time of filling and to an excess of air in the silage resulting in the growth of mould.

The cause of the rise in temperature.—The rise in temperature is presumably connected with the fermentation that takes place in the green corn as a result of which silage is formed. As already stated, this rise in temperature has been attributed by Babcock and Russell, Russell of Rothamstead, and Hart of Wisconsin, to the intromolecular respiration of the ensiled material. Esten and Mason found bacteria and yeasts present in such enormous numbers that they attribute the fermentation which normally occurs to these organisms.

It is generally assumed that the heat is developed as a result of the general process of fermentation which occurs, altho, as indicated, divergent views are held as to the cause of this fermentation. According to Esten and Mason, the fermentation nearly all takes place within the first ten days. Our data with reference to temperatures show that the highest point in temperature comes within a few days and generally before ten days after filling.

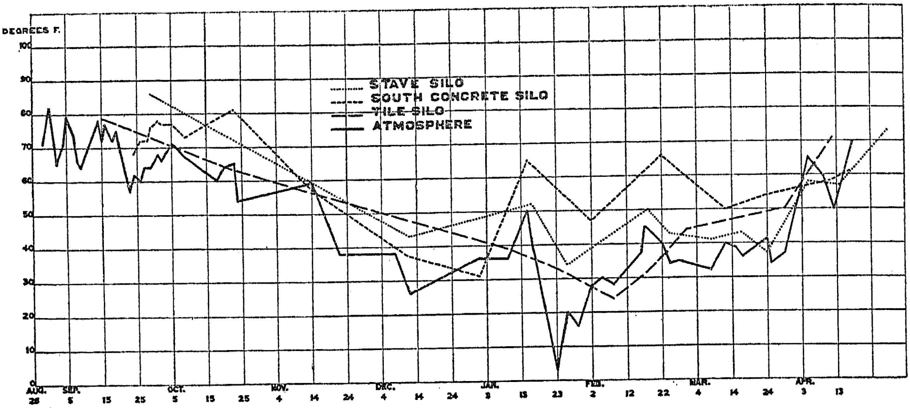

FIG. 4.—TEMPERATURE AT THE WALL OF STAVE, TILE, AND CONCRETE SILOS

The temperature in the tile silo showed the least fluctuation but, like that of the others, followed the air temperature. Based on Table 3.

Influence of air in silage on temperature.—It was noted during the season of 1913-1914 that high temperatures were recorded for the Gurler silo and for one wooden stave silo (Table 4). Both of these silos were filled with corn which was judged to be entirely too dry for good silage. In addition, in both cases the corn was poorly packed in the silo at time of filling. The same conditions were repeated in the season of 1914-1915 in the Gurler silo with the same results as to temperature. Observations made as the silage was removed for feeding showed the presence of some mould throughout the greater part of the silage. The other silos observed the same year (Table 4) showed no mould at any point except on the surface before feeding began. These silos were filled in a proper manner with corn having a sufficient amount of water.

It is a well known fact that very high temperatures, 120-150° F. are found on the upper surface before feeding has begun, apparently connected with the growth of mould. An experiment was planned for the season of 1914-1915 to determine the relation of air, and the growth of mould which results, to the temperature of the silage. Two experimental silos were filled during the first week in September with the same corn which was in a normal condition for silage. The corn was thrown loosely into one silo and no weight applied. The corn in the other was well tramped and a weight of 1500 pounds applied. This is estimated to be the weight to which silage is subjected at a point two-thirds of the distance from the bottom to the top of an average silo.

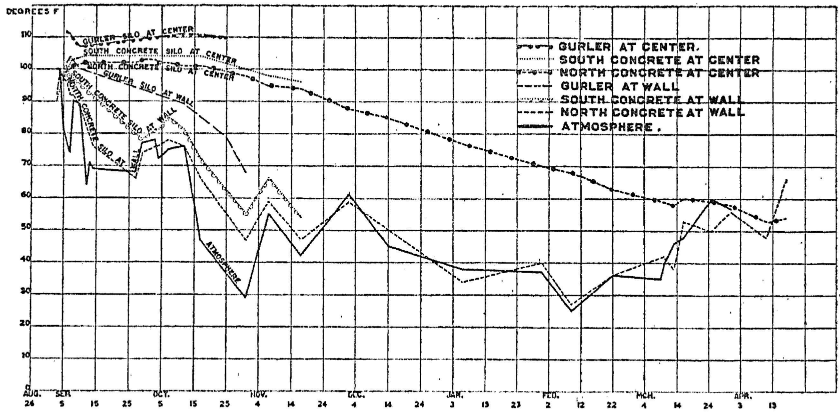

FIG. 5.—TEMPERATURE AT THE CENTER AND AT THE WALL

These temperature readings beginning September, 1913, show a higher starting point due to the high temperature of the air at filling and to the dry condition of the silage put in the Gurler silo. Later changes are similar to those shown in Figures 1 and 3. Based on Table 4.

A resistance thermometer was placed in the center of each. Both silos were opened January 15. The silo in which the loose corn had been placed was rotten for some distance from the top; below this was a large amount of moulded silage, while in the bottom a small amount of normal silage was found. This was apparently due to the fact that the silage contained a high percentage of water and packed itself to some extent and forced the air out. The silo filled with the same corn well packed and with pressure applied was normal in every way, and only a very small amount of mould was found near the edge of the cover. The temperature readings are given in Table 5.

These readings show that the presence of the air in the loosely packed silage made a difference of 23° F. between the maximum temperatures attained by the two silos, and that a higher temperature persisted in the loosely packed silo up to the time of emptying, 137 days later. This higher temperature can only result from oxidation. That such is the case is shown by the wide difference in loss of weight below the screen, where that packed and weighted lost 2.46 per cent, and that not packed became very mouldy and lost 13.93 per cent.

The same experiment was carried out with two experimental silos filled with shock corn January 2, 1915. The fodder was brought directly from the field and run thru the silage cutter. Water at a temperature of 38° F. was added at the rate of one pound for each pound of dry fodder. The fodder was thrown loose into one silo and thoroughly tramped into the other with pressure applied. Both were opened, February 12. There was no evidence that any fermentation

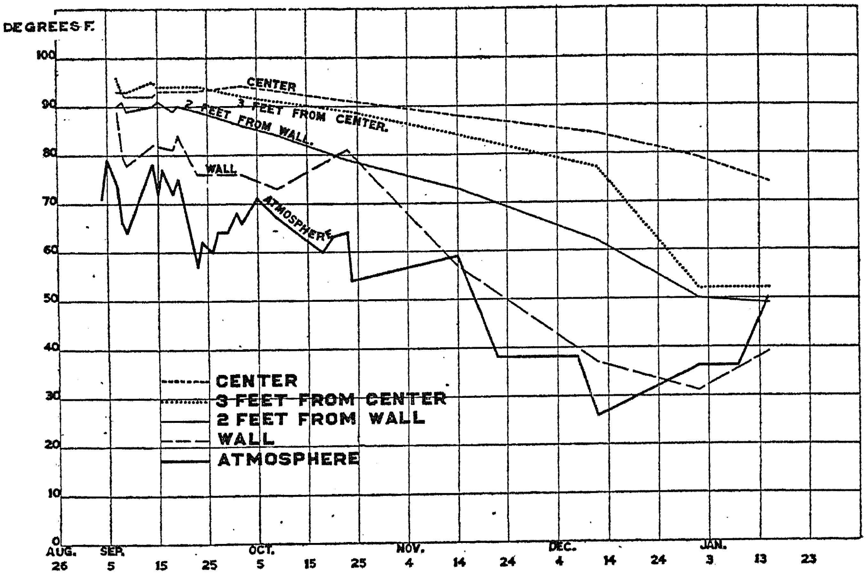

FIG. 6.—VARIATIONS IN TEMPERATURE FROM THE WALL TO THE CENTER IN A CONCRETE SILO

At a point two feet from the wall, the temperature is lower than at the center but declines in the same manner. At a point two or three feet from the center, the temperature is about the same as at the center. Based on Table 3.

had taken place in the silo thoroughly packed and no mould was present except a small amount at the surface. In the other, a large amount of mould was found throughout the contents. The temperature readings are given in Table 5. Uniformly higher temperatures were obtained in the loosely packed silage. Some oxidation evidently had taken place to maintain this higher temperature. This is further shown by the greater loss of dry matter below the screen in the silo not packed.

That packed and weighted lost 1.14 per cent while that not packed was very mouldy and lost 4.03 per cent.

TABLE 5.—INFLUENCE OF AIR UPON TEMPERATURE

Date	Packed	Not Packed	Temperature Air
1914	Degrees F.	Degrees F.	Degrees F.
Experimental Silos[1]			
September 4	79	95	..
September 5	87	110	..
September 7	83	102	..
September 8	84	96	..
September 9	87	92	..
September 10	87	89	..
September 14	74	79	..
September 15	75	81	..
September 17	75	83	..
September 18	76	84	..
September 19	76	85	..
September 22	77	86	..
September 23	76	83	..
September 24	74	80	..
September 28	68	77	..
October 2	68	78	..
October 8	70	80	..
October 13	67	73	..
October 23	63	73	..
November 14	58	63	..
December 5	48	56	..
January 1	31	32	..
January 15	39	42	..
1915			
Experimental Silos[2]			
January 4	36	48	..
January 5	38	76	..
January 6	39	84	..
January 7	40	74	..
January 8	40	65	42
January 9	41	59	48
January 11	42	54	43
January 12	41	51	42
January 13	42	51	50
January 15	43	53	56
January 18	45	52	35
January 21	38	56	30
January 23	35	43	26
January 25	33	39	30
January 29	31	37	29
February 2	32	50	39
February 12	55	53	64

[1] Filled September 2, 1914.
[2] Filled January 2, 1915, with shock corn.

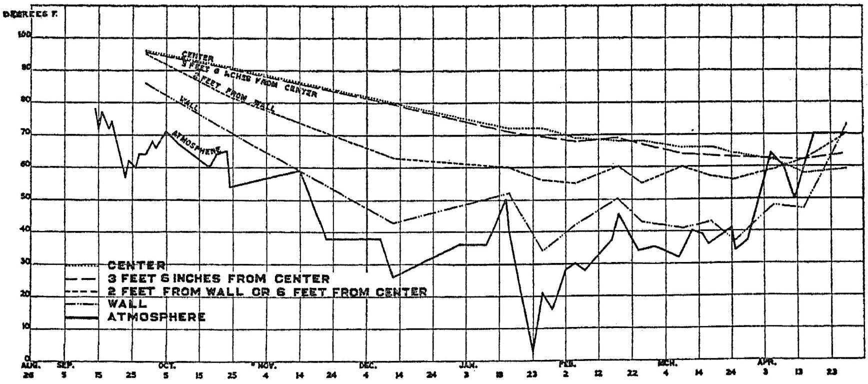

FIG. 7.—VARIATIONS IN TEMPERATURE FROM THE WALL TO THE CENTER IN A STAVE SILO

The variations in temperature in a stave silo are practically the same as those in one made of concrete. Based on Table 3.

Material used in construction of silo.—The competition between builders of different types of silos and the various statements given publicity in this connection has created a wide interest in this particular phase of the subject. If, as has been suggested, the temperature of the silage under normal conditions raises for about 10 days after filling then gradually gives off its heat to the atmosphere, it is possible that the type of construction is a factor in determining the rate at which the heat escapes. The data presented show that such a variation did occur, altho the results are not very marked.

Figure 1 shows that the temperature in the iron silo decreases from 102° at the maximum, to 48° in April. While the North Concrete during the same interval decreased from 78° to 58°, the wooden stave silo from 96° to 58°, the tile silo from 92° to 65°. This shows a greater loss of heat from the iron silo. Attention should, however, be called to the fact that the iron silo was only 12 feet in diameter while the tile silo was 14 and all others were 16 feet in diameter. This smaller diameter may have been as great a factor in the loss of heat as the material used in the wall construction. As between the tile, wooden stave, and concrete silos, there was no material difference in the rapidity with which heat was lost. The records for the season of 1913-1914, altho not as complete as for the season of 1914-1915, indicate the same results as between the silos of the different types.

These data show clearly that the material used in the wall of the silo does not exert any pronounced effect upon the temperature of the silage mass. In this climate at least, this factor need not be given any attention. The relation of the material used in the wall construction to the temperature next to the wall on the inside can be seen from the tables and in Figures 3 and 4. These figures show that the temperatures inside the walls followed that of the air outside rather closely regardless of the material used in the construction of the wall. The temperature in the tile silo seemed to show rather less fluctuation than the others but, like all others, followed the air temperature quite closely.

FERMENTATION AND TEMPERATURE

The question is often raised as to the relation of the temperature in the silo to the quality of the silage produced. This question is usually in connection with that of the efficiency of silos of different construction. Those interested in the manufacture and sale of silos have in some cases been responsible for spreading the statements that silos built of certain materials cause such a loss of heat thru the wall that the temperature of the silage mass is not sufficient for the production of silage of good quality.

Statements that the normal temperature of silage fermentation ranges from 95° to 167° F. and that a temperature under 109° does not give good silage are to be found even in standard text books.[11] On the other hand, Babcock and Russell [12] have shown that high temperatures are not essential to the formation of good silage. According to Esten and Mason [13] the best temperatures for silage formation is between 75° and 85° F., above 100° F. means silage destruction, while below 65° F. a poor quality of silage is produced.

Experimental.—An experiment was planned to further contribute to the knowledge on this subject. Six cans holding about ten gallons each were filled with corn from the large concrete silo while it was being filled. The corn was thoroughly packed in the cans, and covers provided which would slip inside the can. The cans were then placed in a screw press and heavy pressure applied. The lids were securely fastened before the pressure was removed, and the cover was sealed around the edges with paraffin to exclude the air. The weight of the silage in each can was taken both at the time of filling and when the cans were opened.

11 Snyder, H. Chemistry of Plant and Animal Life. 256.

12 Babcock, S. M. and Russell, H. L. Causes Operative in the Production of Silage. Wis. Exp. Sta. Ann. Rept. 1900:123-141.

13 Esten, W. M. and Mason, C. J. Silage Fermentation. Storrs Exp. Sta. Bull. 70. 1912.

Two cans were placed in a cooling room at a temperature of approximately 50° F., two at a temperature of 68° F., and the other two at a temperature of 100° F. The cooling room in which the cans were placed with the intention of holding them at 50° F. varied from 44° to 57° F. at times during the 58 days the test continued. Daily temperature readings showed that only 4 were more than 4 degrees from 50. The temperature within the cans would be subject to considerably less variation as the temperature of the room was corrected within a few hours in most cases. The cans to be held at 68° F. were subject to a variation from 64° to 71° F. All but two readings were within 2 degrees of the desired temperature. The cans to be held at 100° were placed in an insulated box heated with an electric oven with automatic regulation. The daily temperature readings in this box were, with but four exceptions, within three degrees of the desired point.

Twenty-three days after filling, one can from each lot was opened. The silage was compared as to appearance, odor, and taste. Samples were taken for acidity, moisture determinations, and chemical analysis. Slight traces of mould were found in some of the cans indicating that a small amount of air had gained access. The three lots were described as follows:

Can at 50°.—The silage held at 50° F. had 1.94 per cent of acid, and had sustained a loss in weight of 1.26 per cent. The silage had not changed much in color from that of green corn. However, it had a disagreeable odor and taste. The odor indicated the presence of some alcoholic fermentation, with some putrefaction. A few spots of mould were present in this silage next to the seams of the can, but not enough to affect the general results.

Can at 68°.—The silage held at 68° F. had an acid content of 2.19 per cent, and showed a loss in weight of only .27 per cent. This silage was darker than that which had been held at 50° F. It was decidedly sour to taste and had a pleasant acid odor. It also had an odor somewhat characteristic of freshly cut corn.

Can at 100°.—The silage held at 100° F. had 1.45 per cent of acid, and sustained a loss in weight of 2.74 per cent. This silage was the darkest in color of the three lots and was quite similar to that of normal silage. The odor was typical of normal silage, with possibly a somewhat greater amount of alcoholic fermentation. This silage did not taste as strongly acid as that which had been held at 68° F. There was slight evidence of mould but not enough to affect the general results.

TABLE 6.—RELATION OF COMPOSITION TO TEMPERATURE DURING FERMENTATION

Temperature	Days held	Dry matter	Acidity	Protein	Ether extract	Ash	Crude Fiber	Nitrogen free extract
Degrees F.		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
50	23	28.81	1.94	2.89	.67	2.03	7.57	18.08
50	58	28.92	1.56	2.79	.65	1.91	6.52	19.40
68	23	31.00	2.19	3.09	.89	2.06	6.96	20.59
68	58	30.30	2.19	2.97	.87	1.94	6.76	20.25
100	23	29.06	1.45	3.01	.80	2.08	7.78	17.97
100	58	28.90	1.82	2.86	.78	2.00	7.38	17.29

The three remaining cans were opened 58 days after filling with the following results:

Can at 50°.—The silage held at 50° F. had 1.56 per cent of acid. It had a much greener color than the silage in the cans kept at the higher temperatures. It was also greener than silage made from the same corn and taken from the large concrete silo at this time for comparison. The silage had a sharp acid taste, and not an unpleasant odor; although it was not as satisfactory as that from the other two cans. It would pass anywhere as good silage. The odors of alcoholic fermentation, and putrefaction which were noticed in the first can kept at this temperature and opened at the end of twenty-three days was lacking entirely in the contents of this can after the longer interval.

Can at 68°.—The silage held at 68° F. had an acid content of 2.19 per cent, and showed a loss in weight of 1.72 per cent, however, there was no evidence of spoiled silage. The silage was darker in color than that in the preceding can, but not as dark as that which was taken from the south concrete silo at this time. It had a sharp acid taste about similar to that of the preceding can, but with a more pleasant odor. This silage would readily pass for good normal silage.

Can at 100°.—The silage held at 100° F. had 1.82 per cent of acid. It was very nearly of the same color as that which was taken from the south concrete silo; and it was more like it in odor and taste than the silage in either of the other cans. This silage did not taste as sour as that in the other two cans, and was considered by those who examined it to be the best silage of the three lots.

The results of the chemical analysis of the silage from the six cans is given in Table 6. Unfortunately, the sample which represented the corn as put into the cans was spoiled from moulding due to the excessive dampness of the air during the time the sample was drying.

The table, however, shows there was no marked difference in the composition of the silage fermented at the three temperatures used.

The acidity is decidedly the highest in the lot at medium temperatures. The protein shows practically no variation. The ether extract is practically the same in all, or is within the limits of error in making such analyses. There is some difference noticeable in the figures for crude fiber and nitrogen-free extract. It will be noted that, in each case, the percentage of crude fiber decreased between the date of the first sample and that of the second. It would seem safe to attribute this to the effect of the fermentation. The nitrogen-free extract is the highest in the lot at medium temperature and the lowest at the high temperature. In the case of the higher figure, this would bear out the statement of Esten and Mason that temperatures above 100° F. result in silage destruction. The conclusions that can be drawn from these data are that the chemical analyses do not indicate there is any marked difference in the composition of silage fermented at temperatures between 50° and 100° F., the medium temperatures on the whole giving the best results. The highest loss in dry matter occurred at the highest temperature.

It was evident from the odor and taste that there was considerable difference in the character of the fermentation which took place at the three temperatures but the results are not shown to any extent by the chemical analyses. This being the case, the question as to the most desirable temperature for silage formation within these limits is to be decided largely upon the basis of the odor, taste, and palatability of the silage for animals. As noted, the difference was not marked as between the three lots and all would have passed as normal silage although the lot at medium temperature was rather better than the lot at 50°, while that fermented at 100° F. was ranked slightly superior to the medium. These results support the conclusions of Esten and Mason that a medium temperature from 77 to 85 is the most favorable for silage fermentations. Our results indicate that the limits can be extended to 60° and 100° at least without any material difference in the results. Temperatures much above this are not desirable since such a temperature must mean the oxidation or destruction of some of the silage material to furnish the heat.

Relation of type of silo to quality of silage.—The data and conclusions as given in the preceding paragraph show that within rather wide limits, from 60° to 100° at least, no appreciable difference can be detected in either the chemical composition, or the quality of the silage as judged by odor and taste. Data has also been given indicating that under normal conditions the temperature found in any one of the types of silos in common use ranges between 100° and 60° for at least 4 months after filling. There is plenty of evidence at hand to indicate that practically all the fermentation of silage occurs within the first two weeks after filling. Taking these facts into account, it is evident that the quality of the silage produced will not be influenced by any effect upon temperature of the material used in constructing the silo.

SILO-BUILDING MATERIAL AND QUALITY OF SILAGE

The extensive introduction of the silo within recent years has resulted in the use of a number of materials in their construction, among which are wood, iron, brick, glazed tile, and concrete. The question is constantly being raised as to what relation exists between the material used in the construction and the quality and composition of the silage produced. Many opinions have been expressed but little experimental evidence is available. A few observations were published soon after the silo was first introduced and before the present type came into use. Recently, Neidig[14] has shown that the chemical changes during silage formation are the same in silos of different construction.

In connection with the investigations concerning the temperature in different types of silos, samples of silage were taken for chemical analysis. The comparison was made in each case between the silage in the center of the silo and that next to the wall at the same level in the same silo. It is evident that, if there is any difference in the composition of the silage due to the material used in constructing the wall that it should be detected in this manner. While the composition of the silage in different silos may be compared, it must not be expected that the chemical analysis will necessarily be the same, on account of the variations in condition of corn when put into the silos. Even in the same silo, some difference in composition might result from the corn not having been of uniform composition at the wall and center at the time of filling. However, if the material of which the silo is constructed exerts any influence upon the composition of the silage that is worthy of consideration from a practical standpoint, it should show in the chemical analysis.

The samples taken were tested for acidity and moisture and later subjected to chemical analysis. The result of the analyses are given in Table 7. The data in this table show that the percentage of acid at the wall was uniformly lower than at the center of the silo. This was especially noticeable with the Gurler silo in which there was scarcely any acid at the wall. The lower acidity at the wall is probably

[14] Neidig, R. E. Chemical Changes during Silage Fermentation. Ia. Exp. Sta. Res. Bull. 16. 1914.

TABLE 7.—COMPOSITION OF SILAGE AT WALL AND AT CENTER OF SILO

	Acid	Water	Dry Matter	Composition of Dry Matter: Protein	Ether Extract	Ash	Crude Fiber	Nitrogen free extract
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
South Concrete Silo[1]								
Against wall....	2.20	71.07	28.93	9.10	2.70	7.70	21.30	66.85
At center......	2.61	71.42	28.58	9.67	2.06	6.47	22.24	67.69
South Concrete Silo[2]								
Against wall....	1.52	70.52	29.48	8.00	1.48	6.86	27.25	63.14
At center......	2.20	69.66	30.34	8.88	1.95	6.46	23.55	66.61
North Concrete Silo[3]								
Against wall....	1.86	68.04	31.96	6.84	1.87	5.86	28.37	62.80
At center......	2.01	73.64	26.36	7.86	2.52	5.71	24.56	65.95
Gurler Silo[4]								
Against wall....	.02	70.50	29.50	8.52	1.63	7.44	27.76	61.81
At center......	1.04	62.49	37.51	7.32	3.94	5.21	21.83	67.85
Conley's Stave Silo[5]								
Against wall....	1.49	67.84	32.16	9.67	2.03	8.53	26.36	61.55
At center......	2.27	66.83	33.17	7.99	1.92	6.80	24.86	65.15
Reid's Stave Silo[6]								
Against wall....	2.24	71.45	28.55	7.22	6.12	6.32	23.75	56.60
At center......	2.38	71.96	28.04	8.53	7.97	5.78	20.43	57.28
Miller's Stave Silo[6]								
Against wall....	2.29	65.47	34.53	8.38	4.86	6.65	23.44	56.67
At center......	2.35	63.88	36.12	9.12	5.18	6.33	21.07	58.30
Gordon's Tile Silo[6]								
Against wall....	1.46	66.15	33.85	9.51	4.81	7.51	24.58	53.60
At center......	2.20	66.02	33.98	9.03	7.40	4.49	19.60	59.48
Iron Silo[6]								
Against wall....	1.17	74.80	25.20	7.91	4.77	7.02	26.62	53.67
At center......	1.88	74.71	25.29	8.82	3.21	4.99	24.62	58.35

[1] Average of two samples 13 feet below surface of silage, 1914.
[2] Average of two samples 23 feet below surface of silage, 1914.
[3] Taken 18 feet below surface of silage, 1915.
[4] Average of two samples 1913, 10 feet below surface of silage.
[5] Average of two samples, 1914.
[6] 1915.

due to the growth of more or less mould. It is a well known fact that mould neutralizes acid and substances on which it grows usually soon become neutral or alkaline in reaction. While the samples taken at the wall of the various silos did not appear to be mouldy, it is probable that sufficient air had gained access to allow some mould to grow which in turn neutralized or consumed some of the acid. It will be noted that, except with the Gurler, there is no marked difference between the silos of different construction in this respect.

The amount of dry matter shows no difference that can be attributed to the source of the sample. The smaller amount of dry matter in the wall sample from the Gurler silo is due to the addition of considerable water to the silage next to the wall while little or none was added at the center.

The protein figures show considerable variation between the center and wall samples in some cases but no uniformity in variation is to be seen, and certainly no influence can be detected that can be attributed to the kind of silo.

The ether extract shows a wide variation with the different samples but no relation can be observed to the material used in the construction of the silo. No explanation is at hand for the extreme variations to be noted between different silos. The first five samples represent the season of 1913-1914 and have a much lower range than the four remaining samples which represent 1914-1915.

The crude fiber, with one exception, is higher for the wall sample than for the center. In two cases, the difference reaches five per cent. The greatest variation is in those silos where the silage is known to have been in a condition too dry for the best results and was at the same time poorly packed when placed in the silo. It is possible this variation is the result of the difference in fermentation between the wall and center, or it may possibly be attributed to a lack of uniform distribution of the corn grain at filling. It is evident that, whatever may be the cause of the higher crude fiber at the wall as compared with the center, there is no special relation to the construction of the silo that can be observed. The most marked is with the Gurler, the tile stands next, following by one of the concrete, while another concrete shows a reverse result.

The general appearance and palatability of the silage from the different types studied bore out the results of the chemical analyses. So far as could be determined, no particular type of construction among those studied had any advantage over the others. When the silage was properly packed and had sufficient water to exclude the air, it kept perfectly from center to wall in all types studied. The essential things in silo construction are to have an air tight wall smooth on the inside so the silage can settle properly, and sufficiently strong to withstand the pressure of the silage.

The silo buyer will do well to base his choice of a silo upon the first cost, cost of maintenance, and durability of the structure, and not be misled by statements that certain silos will produce silage of a higher feeding value or that others will not keep silage.

ACCURACY OF SMALL SILOS FOR EXPERIMENTAL PURPOSES

In conducting investigations with silos and silage, one of the first questions to be considered is the most feasible silo to be used when a considerable number of tests and comparisons are to be made.

It is obvious that large silos as used in a practical way can not be readily used for many experimental purposes. A large silo requires a large amount of material to fill it to such a point as to make conditions of pressure normal. In carrying on experimental work, it is often desirable to use materials which could not be provided in large quantities without an expense in the way of time and material which would be almost prohibitive. For experimental purposes, it is also desirable to have a silo small enough to allow the silage to be fed out quickly and to reduce the loss to the minimum in case the silage spoils. At the same time, the experimental silo should furnish all the conditions found in the large silo, which are essential for the production of normal silage. The silo should be air tight, capable of withstanding pressure sufficient for packing the silage, and, most important of all, the quality of the silage produced must be the same as that from similar material preserved in an ordinary silo of the size used commercially.

Several kinds of containers have been used by various investigators in conducting experiments with silage, among which are glass jars, even as small as one quart in volume, and metal cans of various sizes, some of which were arranged to telescope together and which are designed to be buried in the silage in a large silo at time of filling. Oil cloth sacks in which a quantity of silage can be buried in a large silo at filling time have been used to some extent by two experiment stations. Barrels have also been tried, but are not successful since the silage does not settle properly due to the curve of the sides. Small silos of various sizes and shapes have also been used by different investigators of this subject. It is reported by Babcock and Russell of the Wisconsin Experiment Station [15] that, where vessels are used ranging in size from a pint to several gallons, and the temperature properly controlled, the silage made is just as good in these small containers held at room temperature (60° to 70° F.) as in large silos where the temperature is much higher, "showing that the accumulation of heat which naturally occurs in a silo when large masses of fodder are ensiled is not at all essential for the production of good silage."

[15] Babcock, S. M. and Russell, H. L. Causes Operative in the Production of silage. Wis. Exp. Sta. Ann. Rept. 1900:123-141.

The same authors[16] used galvanized iron receptacles 1.5 feet in diameter and 4 feet high as silos. The cans were filled with field corn of an average state of maturity and hermetically sealed. The temperature was taken by thermometers inserted thru the cover. The maximum temperature was recorded on the first day. There was a gradual decline to the temperature of the room which was reached about the twelfth day. From this point the temperature of the cans fluctuated with that of the room. The cans were opened on the twenty-fifth day. There was no spoiled silage and it appeared normal in every way.

Test of experimental silos.—In connection with other investigations, comparisons were made of silage from a large silo and that produced in a type of experimental silo which it was proposed to use for preliminary work, at least, in other investigations.

The experimental silos used were water tanks 3 feet in diameter and 6 feet high and were constructed of two inch cypress. A wooden cover was made to fit loosely and was provided with a ring of felt around the edge to make a reasonably tight joint. Weight was applied in the form of 1500 pounds of rock. This was estimated to equal the pressure to which silage is subjected at a point one-third of the distance from the top of a silo containing 28 feet of average silage.

In studying the loss of nutrients in a silo, there are two questions involved. One is the loss at the surface due to exposure to the air, and the resulting growth of organisms; the other is the loss incident to the normal fermentation of the silage. In studying the question of the loss of nutrients, it was desired to separate these two factors. With this object in view, the plan was adopted of placing a wire screen with half-inch mesh in the experimental silos about eighteen inches from the top of the silage at time of filling. Weights were taken of the amount below and above the screen. By rejecting all above the screen when the silo was opened, it was possible to get accurate weights and a fair sample of the silage where it had undergone normal fermentation without any chance to be influenced by the presence of air.

While one of the large silos was being filled, a sufficent amount of the newly cut corn was removed to fill one of the experimental silos. The place where the corn was taken from the large silo was marked by means of a burlap sack and a sample taken for analysis. This procedure was repeated at two points during the filling of the large silos in September, 1913, and once during the season of 1914.

[16] Babcock, S. M. and Russell, H. L. Causes Operative in the Formation of Silage (second paper). Wis. Exp. Sta. Ann. Rept. 1901:177-184.

TABLE 8.—COMPARISON OF SILAGE FROM LARGE SILO AND EXPERIMENTAL SILOS

	Acid	Water	Dry Matter	Composition of Dry Matter				
				Protein	Ether Extract	Ash	Crude Fiber	Nitrogen free extract
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Experimental silo 1, 1913								
Corn as put in....	......	69.19	30.81	7.88	1.74	6.17	26.74	64.09
Silage from experimental silo..	1.80	70.58	29.42	8.03	2.46	5.89	25.15	65.22
Silage from large silo..........	2.01	73.64	26.36	7.86	2.52	5.71	24.56	65.95
Experimental silo 2, 1913								
Corn as put in....	......	71.85	28.15	9.50	2.10	6.66	22.8	66.84
Silage from experimental silo...	2.19	69.91	30.09	9.68	3.15	6.91	19.87	68.52
Silage from large silo.........	2.61	71.42	28.58	9.67	2.06	6.47	22.24	67.69
Experimental silo 1914								
Silage from experimental silo..	2.58	74.41	25.59	......	......	......	......	....
Silage from large silo.........	2.31	72.99	27.01	......	......	......	......	....

When the silage was fed out of the large silos to the marker, a sample was taken and the experimental silo which had been filled with the same corn was opened, the weight of the silage taken and samples taken for comparison and chemical analysis. In each case, several persons familiar with silage were asked to compare the silage from the experimental silo and that from the large silo. The opinion was unanimous that so far as could be determined by odor, taste, and general appearance the silage from the experimental silos was identical in each case with that from the large silo.

In Table 8 are given the chemical analyses of the corn at time of filling in the experiments begun in 1913, and of the silage when removed from the large silo and the experimental silo 134 days later. For the test begun in September, 1914, only the acidity and moisture determinations are available.

A study of these data will show that with the exception of the per cent of ether extract in the silage from Experimental Silo 2 the variations were little, if any, beyond the limits of experimental error. Furthermore such variations as are found are not uniformly in favor of one silo as compared with the other. The acidity, for example, in

TABLE 9.—COMPARISON OF TEMPERATURES IN CONCRETE AND EXPERIMENTAL SILOS

	Concrete Silo		Experimental silo		
	Wall	Center	Wall	Center	Temperature of Air
	Degrees F.	Degrees F.	Degrees F.	Degrees F.	Degrees F.
September 6...	98	100	88	92	79
September 7...	96	101	88	94	74
September 8...	95	102	88	93	90
September 12...	86	102	76	85	64
September 27...	65	102	62	65	68
October 7...	80	102	73	70	75
October 17...	68	100	65	68	47
October 31...	50	98	49	52	29
November 17...	50	95	53	54	42
December 2...	60	89	60	60	61
December 14...	50	85	50	50	45
January 6...	36	80	40	40	38
January 31...	40	73	44	48	37

two cases is higher in the large silos than in the experimental silos, while in the third case the acidity is higher in the small silo.

Experiments with cans.—In the course of another experiment begun September 3, 1914, six tin cans holding about ten gallons each, were filled with cut corn. The corn was thoroughly tramped into these cans, covers to fit inside the cans were put on, and heavy pressure applied by means of a screw press. The lids were wired on before removing the pressure.

The cans were held at temperatures ranging from 50° F. to 100° F., and the silage in all of the cans at the end of 58 days, as determined by acidity, odor, taste and general appearance, would have passed for normal silage. The chemical analyses given in Table 6 indicate normal silage. Unfortunately, the check sample from the large silo which represented the same original corn was injured by moulding and no analysis from this source is available for comparison.

It seems safe to conclude from these results that the small silos used in these experiments gave silage of the same quality as a large silo and, therefore, the results of experiments carried on with the small silos can be relied upon as identical with those from larger silos. For studying normal temperatures in silage, it is evident that the results would not be reliable from the small silos, as is apparent from Table 9. These results bear out the conclusions reached by Babcock and Russell in their investigations.[17]

[17] Same as 16.

SUMMARY AND CONCLUSIONS

1. In the climate of Missouri, the temperature of silage when put in the silo will generally range from 75° to 95° F. The temperature rises from three to fifteen degrees reaching a maximum in from eight to twelve days. From this point on, the temperature of the silage slowly declines. Where sufficient moisture is present, and the silage is well packed, the highest temperature will rarely exceed 100° F. By December 1 the temperature reaches a point between 60° and 70° and the lowest point, 50° to 60°, is reached by March.

2. The temperature in the silage in the early stage is influenced to some extent by the temperature of the atmosphere at time of filling, and of the water used, if any be added.

3. The greatest factor causing variations in the temperature in a silo is the amount of air contained in the silage. It was found, experimentally, that the presence of air, and the resulting growth of mould increased the temperature in every case.

4. The material used in the construction of the silo has but little if any influence upon the temperature of the silage.

5. Good silage was produced at temperatures ranging from 50° to 100° F. Temperature in silos is not an important factor in silage fermentation under practical conditions, since the range of temperatures found in silos under ordinary conditions is entirely within the limits essential for the production of good silage.

6. Analyses of silage from the wall and center of silos of various types of construction showed no difference in composition due to the material used in the construction of the silo.

7. A comparison of silage from a large silo and of silage from the same corn put into a small experimental silo showed the quality to be the same, as judged by appearance and by chemical analysis. For all purposes, except studying temperature changes, the small silo is believed sufficiently accurate for experimental purposes.

8. The factors to be considered in buying or building a silo are economic ones, such as the first cost, cost of maintenance, and durability. The essential things in silo construction are to have (1) an air tight wall, (2) smoothness on the inside so the silage can settle properly, and (4) sufficient strength to withstand the lateral pressure.