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CAPACITIES OF SILOS AND WEIGHTS OF SILAGE

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Capacities of Silos and Weights of Silage

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The extensive use of silos within recent years is responsible for numerous calls for information regarding the capacity of silos of various sizes, and for the weights of silage under a variety of conditions. The occasions for the use of such estimates are: (a) Estimating the capacity of a silo when considering the size to buy or when payment is made by the ton for filling the silo; and (b) buying or selling silage after it has been in the silo for some time. The two problems are somewhat distinct, and clearly no table of figures giving silo capacities will apply equally to a silo recently filled and to one in which the silage has settled from 10 to 20 per cent. Furthermore, when silage is sold the problem is further complicated in many cases by the desire to estimate the amount of silage remaining in the silo after a considerable depth has been fed out.

Practically all tables of silo capacities and silage weights in general use are based upon the work of King. King's table of silage weights, published first in 1891[1] and in a revised form in 1893,[2] is based upon the weights taken of the contents of a limited number of silos, the details of which are not given in full. King recognized the inadequate character of the data in the following statement: "It is important to urge here that the values given must be used with caution for while being the best available at the present time, they are still only rough approximations to those which may be found under varying conditions." The highly important fact should also be kept in mind that King's table is based upon silage that has settled for two days, and not on silage at the time filling is completed. Furthermore, it is not to be applied to the height of the silo itself but to the height of the silage. At the time King's revised table was published, 1893, it was customary to put corn into the silo at a stage considerably greener than is the practice now, which resulted in a higher water content and a greater weight to the cubic foot.

[1]King, F. H. The Construction and Filling of Silos. Eighth Annual Report, Wis. Agri. Exp. Station, pp. 232-261, 1891.

[2]King, F. H. The Silo, Its Construction and Filling. Tenth Annual Report, Wis. Agri. Exp. Sta., pp. 201-227, 1893.

Chase of the Nebraska experiment station after studying the weights taken of corn as put into the silo in several seasons, including twenty silos in all, published a new table giving the capacity of silos at the time filling is completed.[3] In using this table it is assumed that the corn is in a normal condition; that the silo is filled without delay; that two men are kept in the silo tramping during filling; and that the silage is allowed to settle twelve to twenty-four hours and then the silo re-filled. In using the table the depth of the silage rather than the height of the silo is to be considered, and is to apply at the time filling is completed. This table gives figures from 11.5 to 13 per cent lower than those from King's table. A comparison of King's figures with those of Chase is given in an abbreviated form in Table 1.

TABLE 1.—WEIGHT OF SILAGE TO THE CUBIC FOOT—KING AND NEBRASKA TABLES

Depth of silage, feet	Nebraska	King	
	Average weight silage to this depth	Average weight silage to this depth	Weight of silage to the cubic foot at this depth
	lbs.	lbs.	lbs.
2	16.9	19.6	20.4
4	18.4	21.2	23.7
6	19.8	22.9	27.0
8	21.2	24.5	30.1
10	22.6	26.1	33.1
12	23.9	27.6	35.9
14	25.2	29.1	38.7
16	26.5	30.5	41.3
18	27.8	31.9	43.8
20	29.0	33.3	46.2
22	30.2	34.6	48.5
24	31.3	35.9	50.6
26	32.4	37.2	52.7
28	33.4	38.4	54.6
30	34.4	39.6	56.4
32	35.4	40.7	58.0
34	36.3	41.8	59.6
36	37.2	42.8	61.0

The common method for estimating the weight of silage is by the use of tables which are arranged to give the weight of silage when the diameter and depth of the silo or silage are stated. Apparently, all tables for this purpose are based either directly or indi-

[3]Chase, L. W. Measuring Silage and Capacity of Silos. Neb. Agri. Exp. Sta., Circular 1, 1917.

rectly upon the results of King. Some of the tables in common use are published by companies manufacturing or selling silos and others are found in the publications of experiment stations.

The tables commonly used, except the Nebraska table, result as a rule in greatly overestimating the weight of silage. In addition to the fact that even under the best controlled conditions King's table overrates the capacity of the silo, the mistake is commonly made of applying King's figures, which are for silage that has settled two days, to silage in which the settling is completed, or by applying the figures in the table to the full height of the silo rather than to the settled silage. In some of the tables published by the silo manufacturers a still greater error is introduced by using forty-two pounds, the average weight of silage as given by King, as the weight of silage at all depths regardless of the fact that no average weight can apply exept at one certain depth.

Table 2 shows the weight of silage in a silo with a diameter of sixteen feet at various depths as estimated: (a) By the use of

TABLE 2.—CAPACITY AND WEIGHT OF SILAGE IN A SILO SIXTEEN FEET IN DIAMETER AS INDICATED BY VARIOUS TABLES

Depth, feet	King's table (a)	Nebraska table (b)	Silo Mfg. table (c)	Silo Mfg. table (c)	Silo Mfg. table (c)
	Tons	*Tons*	*Tons*	*Tons*	*Tons*
20	66	58.2	80	.....	.....
22	76	66.7	87	.....	.....
24	86	75.5	95	87	.....
26	97	84.6	103	97	.....
28	108	94.1	111	107	.....
30	119	103.8	120	117	.....
32	130	113.8	130	128	131
34	142	124.2	142	139	143
36	154	134.7	155	150	155

(a) Applied to the height of silo as is often erroneously done, not to silage settled two days.

(b) Applied to depth of silage at time filling ceases.

(c) Applied to the height of the silo.

King's table, applying it as is often erroneously done, to the full height of the silage when filling ceases and not to the settled silage, (b) the figures as published by the Nebraska experiment station which are to be applied to the depth of silage at time filling is completed, and (c) the capacity of silos of this diameter of different heights as found in the advertising matter of three prominent silo manufacturers. It will be noted that the Nebraska figures are uni-

formly lower than those by King while the silo capacities as given by the silo manufacturers are decidedly higher. It should also be kept in mind that the figures as given by the silo manufacturers are for the height of the silo itself and not for the depth of the silage. Unless some means is employed whereby it is possible to extend the silage above the top of the silo at filling time the full capacity of the silo can never be used.

The common tendency to overestimate greatly the tonnage of silage results in part from applying these tables of silo capacities which should be applied to settled silage, to the full height of the silo which is not entirely full even when filling is completed. For example, a silo sixteen feet in diameter and thirty-four feet high, according to the table published by one manufacturer, has a capacity of 139 tons. As a matter of fact unless some special provision is made, such as raising the roof at time of filling or using wire fencing to extend the silage above the top of a silo without a roof, it will be impossible for the silage to measure over thirty feet at the time filling is completed.

According to the Nebraska table, thirty feet of silage in a silo of this diameter would represent 103 tons. However, the owner of the silo may assume that he has 139 tons, the amount given by the manufacturer as the capacity of his silo. A further result of so greatly overestimating the capacity of the silo is likewise to overestimate the yield of silage secured from an acre.

Those who have come in close contact with the problems of the silo and silo capacities have long been aware that the table of King, and others based upon it, are too high. It has been the practice of the author in recent years to use King's table but to apply it to the fully settled silage rather than to the depth of the silage after only two days of settling. The same practice is followed by some men in the United States Department of Agriculture.[4] Weights estimated in this manner by use of King's table are more nearly correct than is the case when the same tables are used and applied to the height of the silo as the depth of silage when filling is completed. It should be kept in mind, however, that this plan of using King's table is not in accordance with the original directions of the author, and results in a lower estimate of the tonnage of silage on hand. When used in this manner, however, the figures obtained tend to be too low for a shallow depth of silage and too high for very deep silage.

[4]Homemade Silos, U. S. Dept. of Agri. Farmers' Bulletin 589, p. 7.

SOURCE AND CHARACTER OF DATA USED

This bulletin is based upon a combination of data taken by the Misouri and Kansas agricultural experiment stations. More or less complete weights are available of the contents of thirty-three silos. Of these, twenty-five were filled with corn, five with sorghum, and three with Kafir. The data taken by the Missouri Experiment Station include weights at different depths from fifteen silos containing corn silage. In two silos, the contents were also weighed when put into the silo. Five seasons are represented. The condition of the silage as put in varied widely with the difference in seasons. The rainfall was so deficient at the critical period in the growth of the corn during two of the five years, that while the stalks were large the yield of grain was small. Wide variations in moisture content also existed as a result of the weather conditions and the maturity of the corn when put into the silo. The air-dry matter and water content were determined for all samples used.

The data supplied by the Kansas station represent weights of silage taken at different depths, usually for each foot in depth of silage, for ten silos filled with corn, five with sweet sorghum, and three with kafir.

Method of taking weights.—The weights of silage at different depths were taken by both the Kansas and Missouri experiment stations by means of an apparatus designed by two of the authors and designated hereafter as the Kansas apparatus. The construction of this apparatus is shown in Figure 1. The construction is such that the space within the eight points and the lower bar of the frame is exactly one cubic foot. The manner of using the apparatus is to force the points into the silage until the lower bar of the frame rests on the surface of the silage. The silage is then cut with a hay knife around the points of the apparatus and removed from the center to a level with the end of the points, and weighed. It is found by trial that duplicate samples taken in this manner vary usually not more than two per cent. In one instance all of the fifteenth foot of silage was taken from a silo and the average weight found to be 33.3 pounds to the cubic foot. Samples at the same level taken with the Kansas apparatus showed an average of 33.1 pounds to the cubic foot. In another case all the silage from the twenty-third, twenty-fourth, and twenty-fifth foot depths was weighed and the average weight found to be 36.2 pounds to the cubic foot. The average weight of the same three depths taken with the Kansas apparatus

was 36.8 pounds. In these cases the samples were taken with the apparatus midway between the wall and the center of the silo. Under other conditions the results might not agree so closely with the true weights.

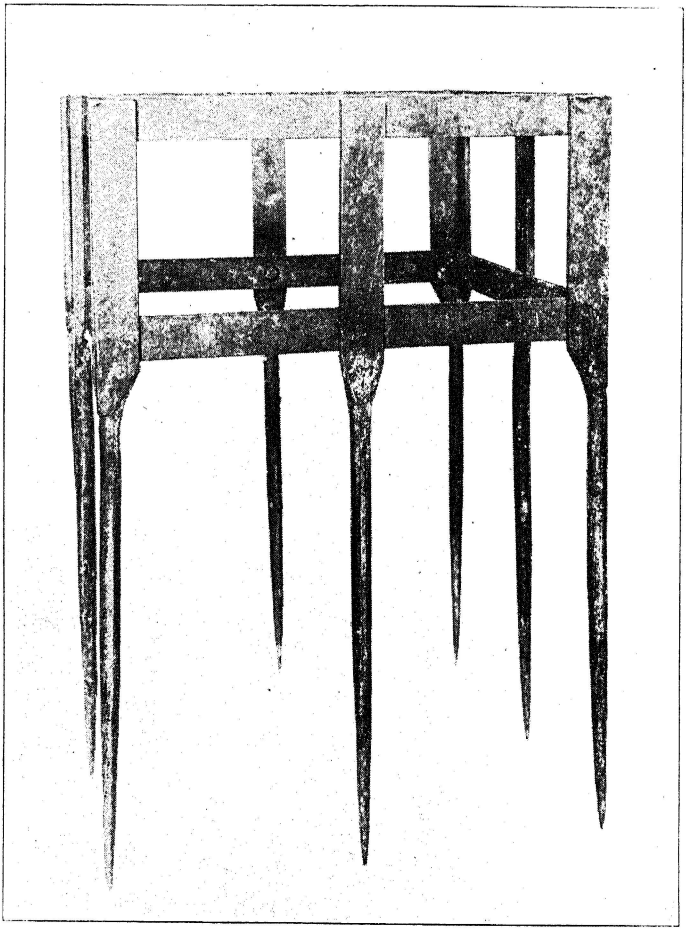

Fig. 1. The Kansas apparatus used in taking the weights of silage to the cubic foot. The points are forced into the silage up to the crossbar, the silage cut around the outside with a hay knife and removed from the center.

It has been found that the weights of silage to the cubic foot in the silo are uniformly higher in the center of the silo than near the wall. Sixty-eight comparisons of weights at the wall and at the center are available from the data taken by the Missouri Experiment

Station with this apparatus. Of these, the average weight at the center was 43.4 pounds to the cubic foot and at the wall 40.5 pounds. The increase in weight from the wall to the center is practically uniform. Assuming this to be the case, the correct average weight theoretically would be 95.2 per cent of the weight taken at the center. The weights given by the Kansas station were taken midway between the wall and the center while the Missouri weights were taken in the center. This small error in the latter data is recognized but on account of the comparatively large limit of error present at best in all estimates of silage weights, no attempt is made to make a correction which necessarily could be based only on average results.

Other questions have been raised regarding the accuracy of such a method on the ground that the silage is elastic and that when the lower part of the silo is reached the volume of the silage would increase as the weight above is removed, and therefore a cubic foot taken by this apparatus would weigh less than a cubic foot when the silo was full. Various observations were made regarding this point. One test was to bury small boards to which wires were attached, at intervals in the silage as the silo was being filled. These wires were carried to the top of the silo and thru pulleys to the outside. Weights were attached sufficient to keep the wires tight. As the silage settled the marker on the outside raised. The maximum point was marked and observations were later made as to the position of the marker when the silage was removed. A small expansion of silage did take place as the silage was removed, but too small to be worth considering in view of the comparatively wide limit of error at best, as mentioned. Further, the small error from this source tends to reduce the weight of the samples taken and to this extent counteracts the error resulting as described from taking the weight in the center. Other less accurate methods of detecting such expansion were all negative.

Dry matter determination.—In taking the data supplied by the Missouri Agricultural Experiment Station, a sample for moisture determination was taken each time the weight of a cubic foot of silage was determined. A sample of two to four pounds was taken from the cubic foot of silage after thoro mixing. This sample was weighed and dried according to the methods in use in chemical laboratories by exposure to air in a warm room until constant weight was reached. Since there was no occasion for making complete chemical analyses of these samples the percentage of moisture-free

material was not determined. The average percentage of moisture in the air-dry samples is available for a large number of silage samples preserved for analysis under similar conditions. This figure does not vary far from six per cent.

The data supplied by the Kansas station included the content of air-dry matter taken in the same manner for the samples from their silos.

EXPERIMENTAL DATA

The data taken on twenty-five silos filled with corn silage is summarized in Table 3. It is noted that the data are not complete for all depths with all the silos. This is the result of various conditions which made it impossible to secure complete data. Some of the weights were taken in silos not under the control of the experiment stations and in some cases feeding of the silage had been under way some time before the taking of the data was begun. In some cases, the weights were taken at intervals of approximately one foot, while in other cases at greater intervals. It is not considered necessary to give the weights taken on each silo in more detail. The figures given for certain depths are the average of all within the limits given. For example, four weights are available on Silo 15 between six and ten feet from the surface. These four weights average 41.2 pounds to the cubic foot.

In addition this table gives the average percentage of air-dry matter, the average weight to the cubic foot as calculated from the cubic-foot samples taken; and for comparison, the weights for the corresponding depths of silage calculated according to King's table. It should be kept in mind, however, that King's table is supposed to be applied to silage two days after filling and not to fully settled silage as is done in this case. A study of this table will show wide variations in the weights in different silos at the same level. The average weights as shown by the cubic-foot samples also vary widely in some cases from the weight as calculated according to King's table. On the whole, the average figures found by applying King's table to settled silage are not so far from correct.

Silo 1 had the greatest weight to the cubic foot of all. At a depth between six and ten feet, for example, the silage in Silo 1 averaged 51.3 pounds, while in Silo 11, having the lowest average weight, a weight of 29.9 pounds to the cubic foot was found for the same level. The contents of Silo 1, on the average, weighed 52.2 pounds to the cubic foot, while King's table applied to the same depth of silage gives an average of 35.2 pounds to the cubic foot.

TABLE 3.—WEIGHT OF SILAGE AND AIR-DRY MATTER TO THE CUBIC FOOT IN TWENTY-FIVE SILOS FILLED WITH CORN

Depth from top, feet	Silo 1	Silo 2	Silo 3	Silo 4	Silo 5	Silo 6	Silo 7	Silo 8	Silo 9	Silo 10	Silo 11	Silo 12	Silo 13	Silo 14	Silo 15	Silo 16	Silo 17	Silo 18	Silo 19	Silo 20	Silo 21	Silo 22	Silo 23	Silo 24	Silo 25
	Lbs	*Lbs*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs*	*Lbs.*
2 to 5	45.6	37.5	.....	.....	29.3	33.1	34.8	27.2	.....	.....	27.8	.....	30.2	33.5	.....	39.3	39.6	.....	39.9	34.3	.....	35.6	.....	.....	.....
6 to 10	51.3	41.7	35.6	34.2	34.4	41.6	37.0	30.9	.....	31.3	29.9	39.1	43.0	35.5	41.2	39.7	42.8	32.2	41.1	39.1	.....	42.0	.....	.....	32.9
11 to 15	57.7	.....	34.2	31 8	36.9	.....	40.8	38.9	45.8	33.2	40.9	38.5	48.7	36.7	46.3	36 0	46.9	39.9	38.7	38.2	35.8	39.4	32.5	.....	34.1
16 to 20	59.1	.....	31.8	29.1	39.8	.....	38.3	.....	47.1	33.2	35.1	41.7	52.5	39.4	49.0	37.4	47.8	41.6	41.9	36.8	38.1	39.8	33.3	34.3	36.6
21 to 25	58.3	.....	.....	32.0	40.0	.....	.....	.....	.....	.....	43.2	52.5	53.0	43.4	49.6	38.5	47.9	.....	.....	40 9	39.0	.....	.....	35.7	37.3
26 to 30	.....	.....	.....	39.8	.....	.....	.....	.....	.....	.....	38.2	.....	.....	51.3	.....	40.1	48.6	.....	.....	42.6	.....	.....	.....	36.8	37.1
31 to 35	.....	.....	.....	40.1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	48.1	.....	.....	.....	.....	.....	.....	.....	.....
36 to 40	.....	.....	.....	38.5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Average weight to the cubic foot, lbs.	52.2	39.8	34.8	34.8	36.7	39.0	37.9	32.7	47.0	32.5	34.3	42.0	45.1	37.9	46.6	38.2	46.6	38.5	40.2	38.3	37.8	39.3	32.7	35.6	35.9
Average percentage air-dry matter	25.9	29.1	37.7	45.6	38.1	31.4	35.1	38.8	31.2	44.5	37.0	30.1	30.2	39.0	34.3	.....	.....	.....	.....	.....	.....	.....	32.6	37.1	36.5
Average weight air-dry matter to the cubic foot, lbs.	13.5	11.6	13.1	15.9	14.0	12.2	13.3	12.7	14.7	14.5	12.7	12.6	13.6	14.7	16.0	.....	.....	.....	.....	.....	.....	.....	10.6	13.2	13.1
Average weight to cubic foot, King's table, lbs.	35.2	26.1	34.4	49.1	36.0	26.5	34.7	30.5	43.0	36.7	39.7	41.0	35.4	37.8	40.2	37.9	43.4	37.8	32.7	38.5	43.7	34.0	39.9	49.8	44.9

FACTORS INFLUENCING THE WEIGHT OF SILAGE WHEN FILLING IS COMPLETED

As indicated by Table 3, the weight of silage is subject to extreme variations. There are several factors that influence the weight and each silo offers an exceedingly complicated problem if an attempt is made to estimate its contents.

Not all the factors influencing the weight of silage when filling is completed enter into the question when fully settled silage is under consideration. At the time filling is completed, the weight to the cubic foot will depend upon six factors.

1. The depth of the silage.
2. The moisture content.
3. The proportion of grain to fodder.
4. The thoroness of packing.
5. The time occupied in filling.
6. The diameter of the silo.

Depth of silage.—The depth of the silage is clearly a factor since the weight to the cubic foot becomes greater with increasing depth. This increase is not regular and gradually diminishes until a point is reached beyond which no further increase in weight is found.

The settling of silage is due to the expulsion of air from among the pieces of silage. The greater the weight the more fully the air is driven out. For this reason it is clear that the average weight to the cubic foot in silage twenty feet deep will be decidedly less than in silage forty feet deep. The weight of silage twenty feet deep should be the same as the first twenty feet of silage forty feet deep. This variation in weight with depth is necessarily much more important at the time filling is completed than after sufficient time has elapsed for settling to take place.

Influence of water content on weight.—In Table 4, are brought together data for seventeen silos giving the average weight of silage to the cubic foot, the percentage of air-dry matter and the weight of air-dry matter to the cubic foot. It is seen that a high average weight to the cubic foot accompanies a low dry-matter content and a high water content. The three lots having the highest weight averaged 48.6 pounds to the cubic foot, and 30.4 per cent of air-dry matter. The lowest three averaged 33.9 pounds to the cubic foot and 40.5 per cent of air-dry matter. However, the ratio between the weight to the cubic foot and the dry-matter content is

not uniform, indicating that other factors are involved; including in some cases, undoubtedly, the wide variation in grain content.

TABLE 4.—THE RELATION OF THE WEIGHT OF SILAGE TO THE DRY-MATTER CONTENT

Silo number	Weight to the cubic foot	Air-dry material	Weight air-dry material to the cubic foot
	Lbs.	*Per cent*	*Lbs.*
1	52.2	25.9	13.9
9	47.0	31.2	14.8
15	46.6	34.3	16.0
13	45.1	30.2	13.6
12	42.0	30.1	12.9
2	39.8	29.1	11.6
6	39.0	31.4	12.2
7	37.9	35.1	13.3
14	37.9	39.0	14.7
5	36.7	38.1	14.0
25	35.9	36.5	13.1
24	35 6	37.1	13.2
3	34.8	37.4	13.1
4	34.8	45.6	15.9
11	34.3	37.0	12.7
8	32.7	38.0	12.7
23	32.6	32.6	10.6

Effect of grain on the weight of silage.—The relation the proportion of grain to forage bears to the weight of silage was tested experimentally. While the filling of a silo on the University of Missouri farm was in progress and the silo half full, a woven wire partition four feet deep was placed in such a manner as to divide the silo into three compartments. One of these compartments was filled with corn in the ordinary manner. The second compartment was filled with more of the same corn except that the ears were removed. The third compartment was filled from the same corn as the first but in addition the grain taken from that put into the second was added. The filling of the silo was then completed, covering the three divisions with ordinary silage. By this means the three experimental lots were subjected to typical silo conditions.

At the time the silage was fed from the three compartments weights were taken from each, the results of which are given in Table 5. This table shows that the silage made from the corn after the ears were removed weighed least to the cubic foot; that from the normal corn weighed more, and the lot containing a double amount of ears weighed most.

Thoroness of packing.—The thoroness of packing is clearly a factor in determining the weight of silage at the time filling is com-

TABLE 5.—RELATION OF PROPORTION OF GRAIN TO WEIGHT OF SILAGE

	Weight, cubic foot	Weight, dry matter to the cubic foot
	Lbs.	*Lbs.*
Corn in normal condition for silage	36.0	14.6
Same corn, ears removed	32.0	8.2
Same corn, ears from second lot added	40.5	17.6

pleted. Thoro tramping and packing results in a more complete expulsion of the air and consequently more weight to a given volume. The effect of the thoroness of packing is more pronounced in the upper layers.

Rate of filling.—The time occupied in filling is also clearly a factor in the weight of silage at the time filling ceases and for some time after. Silage settles slowly, and rapid filling, by giving less time for the air to escape, results in a less tonnage occupying the same space than is the case when more time is given for settling. It is for this reason that when it is desirable to utilize the full capacity of a silo, it is first filled, then allowed to settle two days or more and filled again.

Diameter of the silo and the weight of silage.—The weight of silage averages more to the cubic foot in a silo sixteen feet in diameter than silage from the same corn stored under the same conditions in a silo twelve feet in diameter. King first observed this and stated that the weights of silage vary to some extent with the horizontal dimensions of the silo. Chase makes the same statement. Data taken with the Kansas apparatus show the same facts in a different manner. Data taken by both the Kansas and Missouri experiment stations show that a cubic foot of silage at the center of a silo weighs more than a cubic foot at the wall. These weights were taken in a silo where a silage distributor was used, so that the variations in weight could not be accounted for by assuming that more grain fell in the center than at the wall. Data taken by Darnell[5] of cubic-foot weights between the wall and the center of the silo show a gradual increase toward the center.

In the Missouri data, sixty-eight comparisons are available of weights taken at the center and near the wall at the same level. The average of the weights at the center was 43.4 pounds to a cubic foot and at the wall, 40.5 pounds. In a silo sixteen feet in diameter, the weight of a layer of silage one foot deep would be approximately 95 per cent of the weight in the center. It is readily

[5]Darnell, A. L. Silage Investigations. Thesis for A. M. Degree, University of Missouri, 1916.

seen from these facts that in a small silo where the wall surface is greater in proportion to the volume, the weight of silage to the cubic foot will be somewhat less.

The cause of this variation in weight between the silage at the wall and at the center is probably to be attributed to the friction with the wall, altho some attempt to explain it by assuming that the silage near the center received more tramping during the process of filling. This is questionable, in so far as the silos furnishing the data are concerned, as two men tramped the silage and special care was taken that most of the tramping be done along the wall.

Fineness of cutting.—The possibility of the fineness of the cut being a factor influencing the weight to the cubic foot was tested by dividing the silo into two parts by means of woven wire fencing. In one part, corn cut into three-quarters of an inch lengths was placed; in the other, corn cut in one and a half inch lengths. The filling of the silo was completed in the ordinary manner. When the silo was emptied to this point, the weights were taken for both lots and found to be exactly the same, 36.5 pounds to the cubic foot. In this case, at least, the length of the cut had no effect on the weight of the silage to the cubic foot.

ESTIMATION OF WEIGHT AT TIME FILLING IS COMPLETED

It has been pointed out that there are two distinct conditions under which it is desirable to estimate the amount of silage and that no single table of capacities will apply to both. These are: (a) When filling is completed, and (b) when the silage is fully settled.

The data presented here do not justify any attempt to formulate a table to replace that published by the Nebraska experiment station for estimating the amount of silage at the time filling is completed.[6] The data available, however, do corroborate the statement by Chase that his table tends to give results rather high at times. The conditions under which this table is to be used should also be kept in mind. It should not be applied to the height of the silo but to the depth of the silage when filling is completed. Also, it is to be assumed that two men have been kept in the silo tramping, and that the silage has been allowed to settle one day and then the silo refilled. A portion of the Chase table is reproduced, with the elimination of some of the fractions of tons, in Table 6.

[6]Chase, L. W. Measuring Silage and Capacity of Silos. Neb. Agri. Exp. Sta., Circular 1, 1917.

TABLE 6.—CAPACITY OF SILOS AND ESTIMATED TONNAGE OF SILAGE AT THE TIME FILLING IS COMPLETED*

Depth of silage, feet	Diameter of silo, in feet						
	10	12	14	16	18	20	22
	Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
1	.6	1.0	1.2	1.6	2.1	2.5	3.1
2	1.3	1.9	2.6	3.4	4.3	5.3	6.4
3	2.1	3.0	4.2	5.3	6.7	8.3	10.1
4	2.9	4.2	5.7	7.4	9.4	11.6	14.0
5	3.8	5.4	7.4	9.7	12.2	15.0	18.2
6	4.7	6.7	9.2	12.0	15.2	18.7	22.6
7	5.6	8.1	11.1	14.5	18.3	22.6	27.3
8	6.7	9.6	13.1	17.1	21.6	26.7	32.3
9	7.8	11.2	15.2	19.8	25.1	31.0	37.6
10	8.8	12.8	17.4	22.7	28.8	35.5	43.0
11	10.1	14.5	19.7	25.7	32.6	40.3	48.7
12	11.3	16.3	22.1	28.9	36.6	45.2	54.6
13	12.5	18.1	24.6	32.2	40.7	50.2	60.7
14	13.9	20.0	27.2	35.5	45.0	55.5	67.2
15	15.2	22.0	29.9	39.1	49.4	61.0	73.8
16	16.8	24.0	32.7	42.7	54.0	66.7	80.6
17	18.1	26.1	35.5	46.4	58.8	72.5	87.7
18	19.6	28.3	38.5	50.3	63.6	78.5	95.0
19	21.2	30.5	41.5	54.1	68.6	84.8	102.6
20	22.8	32.8	44.6	58.3	73.8	91.1	110.2
21	24.4	35.1	47.8	62.5	79.1	97.5	118.0
22	26.0	37.5	51.1	66.7	84.5	104.2	126.1
23	27.1	40.0	54.4	71.8	90.0	111.1	134.4
24	29.5	42.5	57.8	75.5	95.5	118.0	142.7
25	31.3	45.2	61.3	80.0	101.3	125.1	151.2
26	33.1	47.7	64.8	84.6	107.2	132.3	160.0
27	34.9	50.3	68.4	89.3	113.2	139.6	168.8
28	36.8	53.0	72.1	94.1	119.2	147.1	177.8
29	38.7	55.8	75.8	98.9	125.4	154.6	187.0
30	40.6	58.5	79.5	103.8	131.6	162.3	196.3
31	.....	61.3	83.4	108.8	137.9	170.1	205.8
32	.....	64.1	87 2	113.8	144.5	178.0	215.2
33	.....	67.0	91.1	118.9	150.8	186.0	225.0
34	.....	69.8	95.1	124.2	157.4	194.1	234.8
35	.....	.....	99.1	129.3	163.9	202.2	244.6
36	.....	.....	103 2	134.7	170.7	210.6	254.8
37	.....	.....	107.2	139.9	177.4	218.8	264.8
38	.....	.....	111.3	145.3	184.2	227.2	275.0
39	.....	.....	115.5	150.8	191.2	235.8	285.4
40	.....	.....	119.6	156.2	198.1	244.3	295.6
41	.....	.....	123.8	161.7	205.1	252.9	305.8
42	.....	.....	128.2	167.4	212.1	261.6	316.3
43	.....	.....	.....	172 9	219.2	270.2	326.9
44	.....	.....	.....	178.6	226.3	279.1	337.6
45	.....	.....	.....	184.2	233.6	288.0	348.4
46	.....	.....	.....	190.0	240.9	297.1	359.4
47	.....	.....	.....	195.8	248.2	306.2	370.4
48	.....	.....	.....	201.8	255.7	315.4	381.4
49	.....	.....	.....	207.7	263.2	324.6	392.5
50	.....	.....	.....	213.6	270.8	333.9	403 7

*The suggestions given on p. 17 should be considered in usging this table.

In estimating the weight of silage at the time filling is completed it is recommended that, when the condition of the corn as put into the silo is average, this table be used as given. If the corn is unusually dry, deduct 10 per cent. If the corn is dry and very little grain is present, deduct 15 per cent. If the silo is filled rapidly and no time allowed for settling deduct 10 per cent.

ESTIMATING THE WEIGHT OF SETTLED SILAGE

The weight of settled silage to the cubic foot is influenced by the same factors as the weight at the time filling is completed but not in the same relative degree. The depth of the silage is a factor but the variation is much less than is the case before settling is complete. This is shown by Table 3. It will be noted that while there is some increase in weight with depth this increase is far less than indicated by the King table. In fact, after a depth of twelve to fourteen feet is reached, there is but little increase with greater depth.

The moisture content of the silage is the most important factor of all in influencing the weight, as shown in Table 4. The feeding value of the silage, however, depends upon the dry matter present and this is subject to far less variation. Silage having a high weight to the cubic foot may not contain any more dry matter than silage having a much lower weight. This is shown in a striking manner in Table 4. Figure 2 represents graphically the proportion of water and air-dry matter in the seventeen silos for which these data are available. This suggests that, after all, the errors made in estimating the weight of silage by the use of tables are not so serious as it at first appears, since under conditions of low water content which tend to cause the weight to be underestimated, the feeding value may really be not so far out of proportion to the estimate. For example, in Table 4, Silo 1 averaged 52.2 pounds to the cubic foot while Silo 8 averaged 32.8 pounds. However, Silo 1 had 13.9 pounds of dry matter to the cubic foot and Silo 8, 12.7 pounds. In this case Silo 1 weighed 59 per cent more to the cubic foot than Silo 8 but the dry matter was only 10 per cent in excess.

The proportion of grain.—The amount of grain in proportion to the forage is of the same importance in estimating the weight of settled silage as when estimating the weight at the time filling is completed.

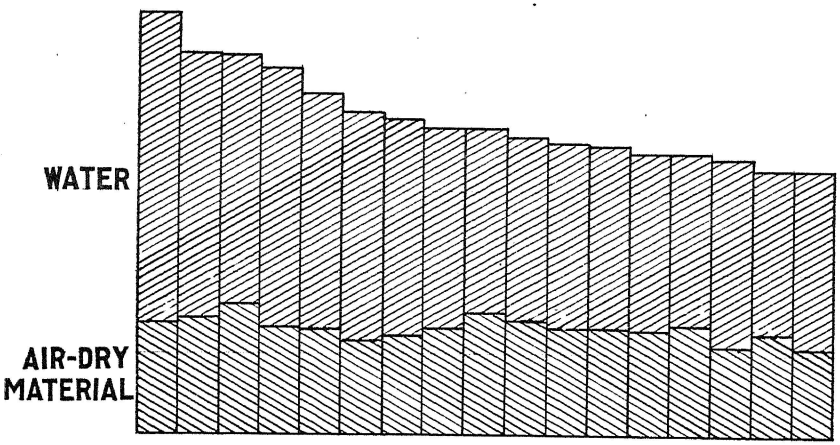

Fig. 2. In this diagram each of the columns represents average weight to the cubic foot of silage in a certain silo. The upper divisions of the columns show the water, and the lower division, the air-dry matter. It shows that the main cause of variation in weight of silage is the water content. The silage represented on the left, altho weighing much more to the cubic foot, contained no more dry matter than others weighing considerably less.

Packing and time of filling.—These factors are of great importance in determining the weight at the time filling is completed but are of minor importance when the silage is fully settled.

Diameter of the silo.—The diameter of the silo is rather more important with settled silage than before settling has been completed.

Data on weights of settled silage.—The new data given concern mostly the weights of settled silage. Table 7 gives a summary of these data. Unfortunately the number of silos represented at a depth of thirty feet or more is small. The decline in the figures as given for weights to the cubic foot beyond a depth of thirty-three feet is to be attributed to the fact that the weight in only one silo was taken at this depth. Attention is called to the fact that the increase in weight to the cubic foot is relatively little after a depth of even ten feet is reached. The figures as found in King's table are given for the sake of comparison. It is seen that his table allows for a much greater increase in weight with increasing depth than was found in the silos from which the data were taken.

It is apparent that the weights given by King for silage at the greater depth are too high. This is shown by the figures as found in Table 3, in which only once did the weights at a depth beyond twenty-five feet approach those given by King. King's maximum figures of sixty-one pounds to the cubic foot at a depth of thirty-six feet is shown to be clearly impossible by the results of tests

TABLE 7.—AVERAGE WEIGHT OF SILAGE TO THE CUBIC FOOT
A Comparison of King's Figures and Results from 25 Silos

Depth of silage, feet	Number of silos represented	Average weight at this depth	King's table
		Lbs.	*Lbs.*
1	....	.....	18.7
2	10	33.7	20.4
3	12	34.2	22.1
4	14	32.0	23.7
5	14	36.0	25.4
6	14	37.7	27.0
7	16	38.4	28 5
8	19	38.5	30.1
9	19	38.3	31.6
10	20	38.4	33.1
11	19	38.3	34.5
12	19	39.4	35.9
13	21	39.9	37.3
14	22	40.2	38.7
15	21	40.6	40 0
16	20	40.5	41.3
17	21	40.5	42.6
18	21	41.2	43.8
19	18	41.7	45.0
20	17	41.1	46.2
21	16	42.0	47.4
22	15	43.1	48.5
23	12	43.1	49.5
24	10	40.4	50 6
25	10	41.2	51.7
26	8	40.8	52.7
27	6	40.0	53.6
28	5	40.7	54.6
29	5	40.3	55.5
30	4	42.2	56.4
31	3	41.5	57.2
32	2	45.2	58.0
33	1	40.0	58.8
34	1	39.6	59.6
35	1	39.2	60.3
36	1	38.7	61.0
37	1	38.2	.....

made to determine the specific gravity of the dry matter of silage by means of the water displacement method. The silage used was made from corn in the proper stage of maturity for silage when cut, but the proportion of grain to forage was only 10 per cent, due to the very unfavorable season. Under normal conditions the grain represents 30 to 35 per cent of the total weight at the time the silo is filled. The specific gravity of the air-dry matter of this silage was 0.619; of the corn grain, 1.162; of the silage with the corn grain removed, 0.559. It was calculated that with silage from

corn grown during a normal year and containing 35 per cent of the weight in the grain, the specific gravity of the dry matter of the silage would be 0.768. Silage contains from eleven to fifteen pounds of air-dry matter to the cubic foot. It is clear then that under no conditions can the weight of silage to the cubic foot equal that of water even when sufficient water is present to completely exclude the air.

Under any conditions estimating the weight of silage from the volume is so uncertain that when silage is sold it is best, when possible, to depend upon weighing it as removed from the silo, rather than upon any estimation made according to volume. The wide range in water content and in the proportion of grain to forage are the two main factors responsible for the variations in the weight of the silage by volume.

Table 8 is designed for use when it is desirable to make an estimation of the weight of settled silage, from the volume. This table should be used only for silage that has settled at least one month and may be used to estimate the amount of silage remaining when a portion has been removed from the silo. When no silage has been removed the depth of the silage is found and the estimated weight of silage readily determined from the table. For example, twenty-five feet of silage in a silo sixteen feet in diameter is estimated by the table to weigh 96.2 tons.

If a portion of the silage has been removed the best plan is to estimate by use of the table the tonnage before any was removed, then by the table to estimate the amount removed. The difference should be the amount on hand. In case the original depth of the settled silage is uncertain, the best plan will be to make the closest estimate possible as to the original depth. Then from Table 6, Column 1, find the estimated average weight to the cubic foot for the silage on hand. For example, it is desired to determine the weight of ten feet of silage remaining in a silo sixteen feet in diameter which contained originally twenty-five feet of settled silage. First, find the average weight of the silage to the cubic foot by averaging the weights to the cubic foot from fifteen to twenty-five feet as given in Table 6, Column 1. This average is 41 pounds. Next, determine the number of cubic feet. To do this, find first the area in square feet of a circle the size of the silo inside, the diameter in this case being 16 feet. To find the area, multiply the square of half the diameter by 3.1416 ($8 \times 8 \times 3.1416 = 201.06$ square feet). The area of the floor of the silo, 201.06 square feet, multiplied by the height of the silage gives the number of cubic feet

TABLE 8.—ESTIMATED WEIGHT OF SETTLED SILAGE*

Depth of silage, feet	Estimated weight of silage to the cubic foot at this depth	Average weight of silage to the cubic foot to this depth	10 ft. diameter	12 ft. diameter	14 ft. diameter	16 ft. diameter	18 ft. diameter	20 ft. diameter
	Lbs.	*Lbs.*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
1	32.0	32.0	1.26	1.81	2.46	3.22	4.07	5.03
2	32.7	32.4	2.54	3.66	4.98	6.51	8.23	10.17
3	33.4	32.7	3.85	5.54	7.55	9.86	12.46	15.40
4	34.1	33.1	5.19	7.48	10.19	13.31	16.81	20.79
5	34.8	33.4	6.55	9.45	12.85	16.78	21.21	26.22
6	35.4	33.7	7.94	11.44	15.56	20.32	25.68	31.75
7	36.0	34.1	9.37	13.50	18.37	23.99	30.31	37.48
8	36.6	34.4	10.80	15.56	21.19	27.66	34.95	43.21
9	37.4	34.7	12.26	17.66	24.04	31.39	39.66	49.03
10	38.0	35.0	13.74	19.79	26.95	35.18	44.45	54.95
11	38.4	35.3	15.25	21.95	29.89	39.02	49.31	60.96
12	38.8	35.6	16.77	24.15	32.89	42.93	54.25	67.07
13	39.2	35.9	18.32	26.38	35.93	46.90	59.27	73.27
14	39.6	36.2	19.90	28.65	39.02	50.93	64.36	79.57
15	40.0	36.4	21.44	30.88	42.04	54.87	69.34	85.72
16	40.2	36.7	23.05	33.21	45.21	59.01	74.57	92.19
17	40.4	36.9	24.63	35.47	48.30	63.04	79.67	98.49
18	40.6	37.1	26.22	37.76	51.42	67.11	84.81	104.84
19	40.8	37.3	27.83	40.07	54.56	71.22	90.00	111.27
20	41.0	37.5	29.45	42.41	57.75	75.38	95.25	117.75
21	41.2	37.6	31.00	44.65	60.79	79.35	100.28	123.97
22	41.4	37.8	32.65	47.02	64.03	83.58	105.61	130.56
23	41.6	38.0	34.32	49.41	67.29	87.84	110.50	137.22
24	41.8	38.1	35.90	51.70	70.40	91.90	116.13	143.56
25	42.0	38.3	37.60	54.15	73.72	96.23	121.60	150.33
26	42.2	38.4	39.20	56.46	76.87	100.34	126.80	156.75
27	42.4	38.6	40.92	58.94	80.24	104.74	132.36	163.63
28	42.6	38.7	42.55	61.28	83.43	108.90	137.62	170.13
29	42.8	38.9	44.30	63.79	86.86	113.37	143.27	177.11
30	43.0	39.0	45.94	66.08	90.09	117.59	148.59	183.69

*The suggestions given on p. 22 should be considered in using this table.

(201.06 x 10=2010.6 cubic feet). The number of cubic feet multiplied by the weight to the cubic foot gives the total weight (2010.6 x 41=82,434 pounds or 41 tons and 434 pounds).

It will be noted that Table 8 makes no provision for depth of silage beyond thirty feet. The data at hand for the weight of settled silage in excess of this depth were too limited to justify continuing the estimate further. An examination of Table 3, however, shows that the increase in weight with increasing depth is very small after even a depth of twelve to fifteen feet is passed. Column 1 in Table 6 which is based upon a study of all data available gives the increase in the weight to the cubic foot from a depth of

twenty-five to thirty feet as one pound to the cubic foot. On account of the extremely small increase as shown (and this rate of increase decreases presumably as greater depths are reached) it is believed the fairest plan is to assume a constant weight for a depth of silage beyond that shown in the table. The weight assumed is forty-three pounds to the cubic foot. By this plan, for each additional foot of silage in depth in excess of thirty feet, add to the total as given by the table for thirty feet a sum found by multiplying the depth in feet in excess of thirty by the tons of silage to the foot, which is estimated as follows:

Diameter of Silo	Weight, Silage 1 foot in depth
10 feet	1.69 tons
12 feet	2.43 tons
14 feet	3.31 tons
16 feet	4.31 tons
18 feet	5.47 tons
20 feet	6.26 tons

It should be kept in mind that in using this table it represents average conditions in Kansas and Missouri. The proportion of grain to forage is an important factor in determining the weight. In more northern latitudes the proportion of grain is higher and this would tend to increase the weight to some extent, while farther south, with the smaller proportion of grain, the reverse would be true. Furthermore, when extreme conditions of any kind prevail it is wise to make some allowances, and the following are suggested:

1. When the corn is put into the silo in a less mature condition than usual, for example, in the milk stage, or at the beginning of the dough stage, add 10 to 15 per cent to the weights given in the table.

2. If the grain is unusually heavy in proportion to the stalk, add 5 to 10 per cent to the figures as found by the table.

3. If the corn is considerably past the usual stage of maturity and clearly contains less water than usual, deduct 10 to 15 per cent.

4. If very little or no grain is present, deduct 10 per cent.

ESTIMATING THE WEIGHT OF SWEET SORGHUM AND KAFIR SILAGE

The increasing use of sweet sorghum and kafir for silage raises the question as to the weight of silage from these crops. Data by the Kansas station are available for weights taken of sorghum silage

in four silos. Unfortunately, these data do not cover the complete contents of the silo. In one the depth included was from 17 to 49 feet, in another, from 1 to 16 feet. The air-dry content of the samples taken varied from 33 to 38 per cent, which is normal for silage made from sorghum in the proper stage of maturity. It should be kept in mind, however, that the sorghum from which this silage was made was in the stage when the seeds are in the dough condition. Sorghum is often put into the silo at earlier stages but the results are not so satisfactory and the water content is higher. Data from the Kansas station are also available for the weights of kafir in three silos; one of them for depths from one to forty-five feet.

A summary of the available data on the weights of silage from these crops at different depths in comparison with corn is given in Table 9. It will be noted that the figures given for sorghum silage

TABLE 9.—COMPARISON OF THE WEIGHTS OF CORN, SORGHUM, AND KAFFIR SILAGE

Depth of silage, feet	Average weight to the cubic foot		
	Corn *Lbs.*	Sorghum *Lbs.*	Kaffir Corn *Lbs.*
6 - 10	36.6	30.4	34.6
11 - 15	39.2	34.0	34.7
16 - 20	40.6	40.8	36.6
21 - 25	41.6	42.0	38.0
26 - 30	42.2	44.0	39.6

are less than those for corn up to fifteen feet, and more at greater depths. This inconsistency is to be attributed to the limited amount of data available for the sorghum, and not to a tendency to increase in weight more rapidly than corn as the depth is increased. The figures for kafir are uniformly lower than the average for corn. The data, however, are very limited, the greater part coming from one silo.

The variation in weights between corn silage and sorghum and kaffir as shown is not extreme and in view of the limited amount of data available it seems advisable to use the same table as recommended for corn to estimate the tonnage of sorghum or kafir silage.

SUMMARY AND CONCLUSIONS

This publication is based upon a combination of data taken by the Kansas and Missouri agricultural experiment stations.

The weight of silage to the cubic foot was taken, by means of an apparatus designed for the purpose, in a total of thirty-two silos

representing five seasons. The weights were taken as the silo was emptied; in some cases for each foot of depth of silage, in others, less frequently.

The tables of silage weights and silo capacities now in use are either King's, published in 1893, or modifications of his table. A modification of King's table published by the Nebraska experiment station gives reasonably accurate results when used, as specified by the author, to estimate the weight of silage at the time filling is completed. None of the tables so far published is adapted to estimating the weight of settled silage.

The weight of silage is subject to so much variation and is influenced by so many factors that no table can be more than approximately correct. The chief factors influencing the weight of settled silage are: (1) The percentage of water in the corn, (2) the proportion of grain to forage, (3) the depth of the silage, and (4) the diameter of the silo. At the time filling is completed and before settling has taken place, the rate of filling and the thoroness of packing are also important factors.

It was found experimentally that the proportion of grain influenced the weight of silage to the cubic foot but that the fineness of cutting did not appear to be a factor.

A new table is given based upon experimental data and designed for use in estimating the weight of settled silage.

Weights on the contents of three silos containing sweet sorghum silage, and three containing kafir silage showed no wide variations in weight as compared to corn silage, and it is recommended that, until more data are available, the same table as designed for use with corn silage be used in estimating the weight of silage from these crops.

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