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CAPACITY OF SILOS AND WEIGHTS OF SILAGE

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SUMMARY

1. The data herein reported were obtained by the Missouri and Kansas Agricultural Experiment Stations from thirty-two silos—twenty-five filled with corn, four filled with sweet sorghum, and three filled with kafir.

2. In finding the weights of silage per cubic foot an apparatus designed especially for the purpose was used. The weights were determined as the silos were emptied; in some cases for each foot of depth.

3. The tables of silage weights now in use are King's table, published in 1893, or modifications of this 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. No table heretofore published is adapted to estimating the weight of settIed silage.

4. 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) Percentage of water; (2) proportion of grain to fodder; (3) depth of silage; and (4) diameter of silo. AT the time filling is completed and before settling has taken place, the rate of filling and the thoroughness of packing are also important factors.

5. It was found experimentally that the fineness of cutting did not appear to influence the weight of silage.

6. A new table is given, based upon experimental data, and designed for use in estimating the weight of settled silage. (See page 20.)

7. Weights on the contents of four silos containing sweet sorghum and three containing kafir showed no wide variations in weight as compared with corn silage. It is recommended that until more data are available, the table used for corn silage be used also for estimating the weight of silage made from the sorghums.

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THE CAPACITY OF SILOS AND WEIGHTS OF SILAGE

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PREVIOUS INVESTIGATIONS

The extensive use of silos within recent years is responsible for numerous calls for information regarding the capacity of silos and for the weights of silage under a variety of conditions. The occasions for the use of such estimates arise: (1) When considering the size of silo to buy or when paying by the ton for filling a silo; and (2) when 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 both—a silo recently filled and one in which the silage has settled from 10 to 20 percent. The problem is further complicated in many cases by the desire to estimate the amount of silage remainingin a silo after a portion has been fed.

Practically all tables of silo capacities and silage weights in general use are based upon the work of King of the Wisconsin Agricultural Experiment Station, published first in 1891[2] and published in a revised form in, 1893.[3] King's table is based upon 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

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[1]During the time most of the investigations herein reported were carried on by the Missouri and Kansas Agricultural Experiment Stations, C. H. Eckles was in charge of Dairy Husbandry at the Missouri station and O. E. Reed in charge of Dairy Husbandry at the Kansas station. C. H. Eckles is responsible for the interpretation of the data and for the preparation of the material for publication. Bulletin 164 of the Agricultural Experiment Station, University of Missouri, "Estimating the Capacity of Silos and Weights of Silage," presents the same data as herein reported in substantially the same form.

[2]King, F. H. The construction and filling of silos. Wis. Agr. Expt. Sta. Eighth Ann. Rpt. Pp. 232-261. 1891.

[3]King, F. H. The silo, its construction and filling. Wis. Agr. Expt. Sta. Tenth Ann. Rpt. Pp. 201-227. 1893.

ACKNOWLEDGMENT.—The authors desire to acknowledge their indebtedness to O. I. Oshel, A. L. Darnell, L. W. Wing, Jr., and M. H. Fohrman, graduate students in Dairy Husbandry, University of Missouri, who are responsible for taking the data supplied by the Missouri Agricultural Experiment Station; and to H. W. Cave, graduate student in Dairy Husbandry, Kansas State Agricultural College, who assisted in taking the data contributed by the Kansas Agricultural Experiment Station.

actually be found under varying conditions." The important fact that King's table is for silage that has settled for two days, and not for silage at the time filling is completed, should also be kept in mind. Furthermore, it should not be applied to the height of the silo itself, but to the height of the silage. When King's revised table was published in 1893, it was customary to put corn into the silo at a stage greener than is the practice now, which resulted in a higher water content and a greater weight per cubic foot.

Chase of the Nebraska Agricultural Experiment Station, studied the weights of corn silage put into 20 silos in several seasons, and published a table giving the capacity of silos at the time filling is completed.[1] This table is for corn silage in a normal condition, put into the silo without delay, tramped by two men during filling, and allowed to settle 12 to 24 hours, the silo then being refilled. The table should be applied to the depth of the silage when filling is completed, rather than to the height of the silo. It gives results varying from 11.5to 13 percent lower than those given by King's table. A comparison of the two tables is given in an abbreviated form in Table I.

Since most of the tables commonly used are based on King's work, they generally give weights that are too high for present

TABLE I.—WEIGHT OF SILAGE PER CUBIC FOOT, KING AND NEBRASKA TABLES

Depth of silage	Nebraska	King	
	Average weight of silage to this depth	Average weight of silage to this depth	Weight per cubic foot at this depth
Feet	*Pounds*	*Pounds*	*Pounds*
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

[1] Chase, L. W. Measuring silage and capacity of silos. Nebr. Agr. Expt. Sta. Cir. 1:1-14. 1917.

conditions. In addition, the mistake is commonly made of applying King's figures to silage which is completely settled, although they were intended only for silage that has settled two days. Also, the figures are sometimes applied to the full height of the silo, instead of to the settled silage. In some of the tables published by the silo manufacturers, a still greater error is introduced by using 42 pounds, the average weight of silage as given by King, for all conditions, regardless of the fact that no average weight can apply to all depths and sizes.

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

Depth	King's table (*a*)	Nebraska table (*b*)	Silo manufacturers' tables (*c*)		
Feet	*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 the depth of silage at the time filling is completed.
(*c*) Applied to the height of the silo.

Table II shows the weight of silage in a silo with a diameter of 16 feet at various depths as estimated by (1) King's table, applying it, as is often erroneously done, to the full height of the silo and not to the settled silage; (2) Chase's table, which should be applied to the depth of silage at the time filling is completed; and (3) tables given in the advertising matter of three prominent silo manufacturers. It will be noted that the Nebraska figures are uniformly lower than those secured by King, while those given by silo manufacturers are decidedly higher. For example, a silo 16 feet in diameter and 34 feet high, according to one manufacturer, has a capacity of 139 tons. But such a silo cannot be filled sufficiently to hold more than about 30 feet of settled silage, unless the top of the silo is extended at filling time by raising the roof or by means of wire netting. According to the Nebraska table, this silo would hold 103 tons instead of 139. Another result of overestimating the capacity of a silo is to overestimate the yield of silage per acre. 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.

Those who have come in close contact with the problems of measuring silage and silo capacities, have long been aware that King's table and others based upon it, give results which are too high. It has been the practice of one of the authors, in recent years, to apply this table 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.[1] Weights estimated in this manner are more nearly correct than if the same tables are applied to the height of the silo. This plan, however, is not in accordance with the original directions of the author. Also, when used in this manner, the figures obtained are likely to be too low for a shallow silo and too high for a very deep silo.

EXTENT OF INVESTIGATIONS HEREIN REPORTED

Results presented in this bulletin are based upon data secured by the Missouri and Kansas Agricultural Experiment Stations. More or less complete weights of the contents of 32 silos are available. Of these, twenty-five were filled with corn, four with sweet sorghum, and three with kafir.

The data from the Missouri station include weights at different depths from 15 silos filled with corn. Five seasons are represented. In two silos, the contents were weighed when put into the silo. The air-dry matter and water content were determined for all samples used. The condition of the crop when put in varied widely with the season. The rainfall was so deficient at the critical period in the growth of the corn in two of the five years, that while the stalks were large, the yield of grain was small. There were also variations in moisture content as a result of the weather conditions and the maturity of the corn.

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

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[1]Rabild, Helmer, and Parks, K. E. Homemade silos. U. S. Dept. of Agr. Farmers' Bul. 855:1-55. Figs. 47. 1917.

METHOD OF DETERMINING WEIGHTS

The weights of silage were determined by means of an apparatus designed by two of the authors and designated hereafter as the Kansas apparatus. This apparatus is illustrated in figure 1. The construction is such that the space within the eight points and the lower bar of the frame is exactly one

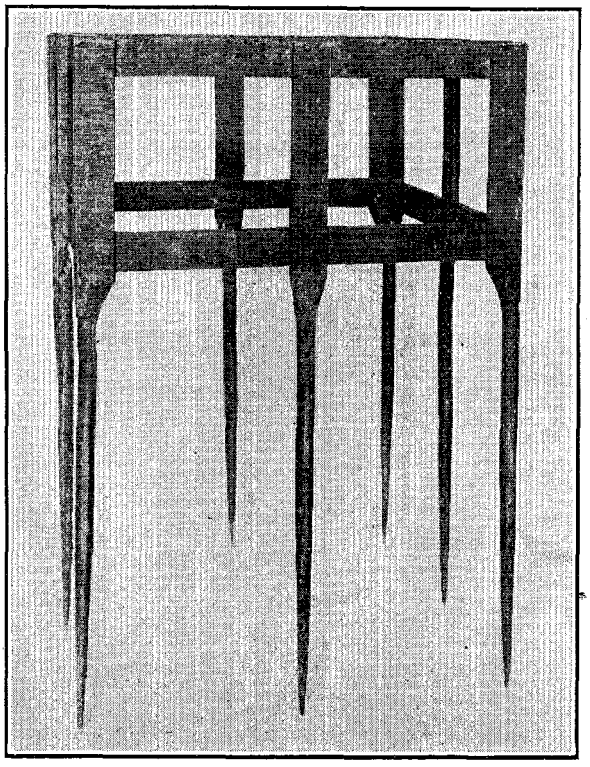

FIG. 1.—Apparatus used in determining the weight of a cubic foot of silage

cubic foot. The apparatus is forced into the silage until the lower bar of the frame rests on the surface of the silage. The silage around the points of the apparatus is then cut with a hay knife and removed from the center to a level with the end of the points, and weighed. Duplicate samples taken in this manner were found to vary usually not more than 2 percent. In one instance, all of the fifteenth foot of silage was found to average

33.3 pounds per cubic foot. Samples at the same level taken with the Kansas apparatus gave an average of 33.1 pounds per cubic foot. In another case all the silage from the twenty-third, twenty-fourth, and twenty-fifth foot depths, was weighed and found to average 36.2 pounds per cubic foot. The average weight of the same three depths as determined by the Kansas apparatus was 36.8 pounds per cubic foot. In these cases the samples were taken with the apparatus midway between the wall and the center of the silo.

It has been found that the weights of silage per cubic foot are uniformly higher in the center of the silo than near the wall. At the Missouri station 68 comparisons of this kind were made. Of these, the average weight per cubic foot at the center was 43.4 pounds and at the wall, 40.5 pounds. The increase in weight from the wall to the center is practically uniform. Assuming a uniform increase, the correct average weight would be 95.2 percent of the weight taken at the center. The weights secured at the Kansas station were taken midway between the wall and the center while those from Missouri station were from the center. This small error in the latter data is recognized, but on account of the comparatively large errors present in all estimates of silage weights, no correction is attempted.

The accuracy of this method has been questioned on the ground that silage is elastic, that as the lower part of the silo is reached and the weight above removed the volume of the remaining silage would increase, and that, therefore, a cubic foot taken by this apparatus would weigh less than a cubic foot when the silo was full. Several observations were made regarding this point. One test was conducted by burying small boards to which wires were attached, at intervals as the silo was being filled. These wires were carried to the top of the silo and, through pulleys, to the outside. Weights, sufficient to keep the wires tight, were attached. As the silage settled, the markers on the outside were raised. Their location was marked and observations as to the position of the markers when the silage was removed were later made. A small expansion was found to take place as the silage was removed, but too small to be worth considering in view of the other sources of error. Other less accurate methods for detecting the expansion gave negative results.

Representative samples for moisture determination were

secured each time the weight of a cubic foot of silage was determined. These samples were weighed and dried to constant weight by exposure to the air in a warm room. Since there was no occasion for making complete chemical analyses of these samples, the percent of moisture-free material was not determined. As shown by a large number of determinations in other experiments, it is known that air-dry silage contains not far from 6 percent of moisture.

ESTIMATING WEIGHTS OF CORN SILAGE

WEIGHTS DETERMINED

The weight per cubic foot, average percent of air-dry matter, and average weight of air-dry matter per cubic foot in 25 silos filled with corn, are given in Table III. The average weight per cubic foot according to King's table is also included in this table. The data are not complete for all depths of all the silos. Some of the weights were from silos not under the control of the experiment stations and in some cases a part of the silage had been fed 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. Where more than one determination was made the average only is given. For example, four determinations on silo No. 15 between 6 and 10 feet from the surface were made. The average was 41.2 pounds, which is the figure reported in the table.

In comparing the results with King's table, it should be kept in mind that the latter is supposed to be applied two days after filling is completed and not to fully settled silage.

A study of this table shows wide variations in the weight per cubic foot of silage in different silos at the same level. The average weight also varies, 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 far from correct.

Silo No. 1 contained the heaviest silage of all. At a depth between 6 and 10 feet, for example, the silage in this silo averaged 51.3 pounds per cubic foot, while in silo No. 11, it averaged 29.9 pounds for the same level. The entire contents of silo No. 1 averaged 52.2 pounds per cubic foot, while King's table applied to the same depth of silage gives an average of only 35.2 pounds per cubic foot.

TABLE III.—WEIGHTS OF SILAGE AND AIR-DRY MATTER PER CUBIC FOOT IN TWENTY-FIVE SILOS FILLED WITH CORN

Depth	Silo No. 1	Silo No. 2	Silo No. 3	Silo No. 4	Silo No. 5	Silo No. 6	Silo No. 7	Silo No. 8	Silo No. 9	Silo No. 10	Silo No. 11	Silo No. 12	Silo No. 13
Feet	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
2 to 5	45.6	37.5	.....	.....	29.3	33.1	34.8	27.2	.....	.....	27.8	.....	30.2
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
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
16 to 20	59.1	.....	31.8	29.1	39.8	.....	38.3	.....	47.1	33.2	35.1	41.7	52.5
21 to 25	58.3	.....	.....	32.0	40.0	.....	.....	.....	.....	.....	43.2	52.5	53.0
26 to 30	.....	.....	.....	39.8	.....	.....	.....	.....	.....	.....	38.2	.....	.....
31 to 35	.....	.....	.....	40.1	.....	.....	.....	.....	.....	.....	.....	.....	.....
36 to 40	.....	.....	.....	38.5	.....	.....	.....	.....	.....	.....	.....	.....	.....
Average weight	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
Average percent of 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
Average weight of air-dry matter	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
Average weight according to King's table	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

TABLE III.—CONCLUDED

Depth	Silo No. 14	Silo No. 15	Silo No. 16	Silo No. 17	Silo No. 18	Silo No. 19	Silo No. 20	Silo No. 21	Silo No. 22	Silo No. 23	Silo No. 24	Silo No. 25
Feet	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
2 to 5	33.5	.....	39.3	39.6	.....	39.9	34.3	.....	35.6	.....	.....	.....
6 to 10	35.5	41.2	39.7	42.8	32.2	41.1	39.1	.....	42.0	.....	.....	32.9
11 to 15	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	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	43.4	49.5	38.5	47.9	.....	.....	40.9	39.0	.....	.....	35.7	37.3
26 to 30	51.3	.....	40.1	48.6	.....	.....	42.5	.....	.....	.....	36.8	37.1
31 to 35	.....	.....	.....	48.1	.....	.....	.....	.....	.....	.....	.....	.....
36 to 40	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Average weight	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 percent of air-dry matter	39.0	34.3	.....	.....	.....	.....	.....	.....	.....	32.6	37.1	36.5
Average weight of air-dry matter	14.7	16.0	.....	.....	.....	.....	.....	.....	.....	10.6	13.2	13.1
Average weight according to King's table	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 III, the weight of silage varies greatly. There are so many factors involved that an estimation of the contents of each individual silo offers an exceedingly complicated problem.

When filling is completed, the weight of silage per cubic foot will depend upon at least six factors, as follows: (1) Depth of silage; (2) moisture content; (3) proportion of grain to fodder; (4) thoroughness of packing; (5) rate of filling; and (6) diameter of the silo.

Depth of Silage.—The weight of silage per cubic foot increases with the depth. This increase is not regular but 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. The greater the weight the more fully the air is driven out. The increase in weight with depth is greater at the time filling is completed than after sufficient time has elapsed for settling to take place.

Moisture Content.—A study of the average weight of silage per cubic foot, the percent of air-dry matter, and the weight of air-dry matter per cubic foot as presented in Table III shows that high average weight accompanies a low dry-matter content and high water content. The relation of the average weight of silage per cubic foot to the average weights of air-dry matter and water per cubic foot, for 17 of the 25 silos on which weights are given in Table III, is shown graphically in figure 2. The three silos having the highest weight averaged 48.6 pounds per cubic foot and 14.7 pounds per cubic foot (30.4 percent) of air-dry matter. The lowest three averaged 32.6 pounds per cubic foot and 12 pounds per cubic foot (38.6 percent) of air-dry matter. The ratio between the weight per cubic foot and the air-dry matter is not uniform, however, indicating that other factors are involved.

Proportion of Grain to Fodder.—The relation which the proportion of grain to forage bears to the weight of silage was determined experimentally, at the Missouri station. While filling was in progress and the silo half full, a woven wire partition four feet high was placed in such a manner as to divide the silo into three compartments. One of these compart-

ments was filled with corn in the ordinary manner. The second compartment was filled with corn from the same field, but with the ears removed. The third compartment was filled from the same field and in the same way as the first, but with the addition of the grain taken from that put into the second compartment. 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 similar conditions.

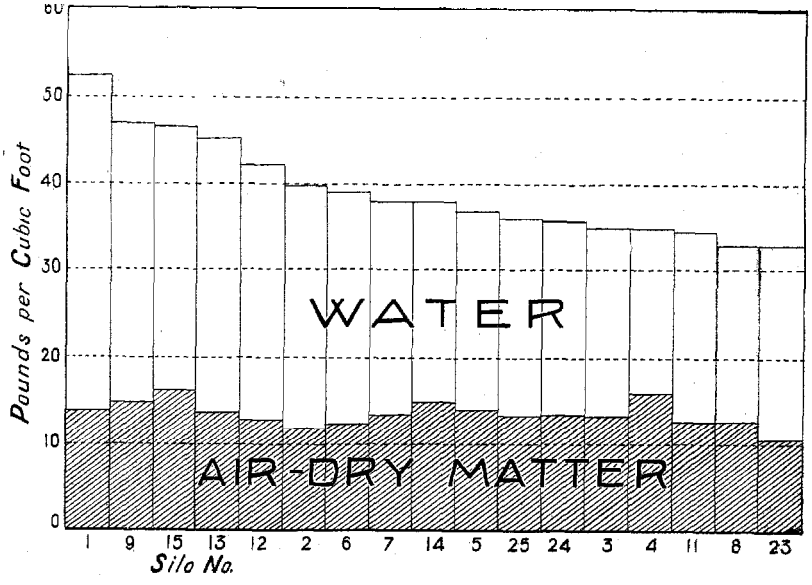

FIG. 2.—Graphical representation of the relation of the weight of silage per cubic foot to the weight of air-dry matter contained

When the silage was fed, the weights per cubic foot of silage from the three compartments were determined. The results are given in Table IV. It will be seen that silage made from corn after the ears were removed, weighed least, silage made from normal corn weighed more, and that containing a double amount of ears weighed most.

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

Kind of silage	Weight of silage per subic foot	Weight of air-dry matter per cubic foot
	Pounds	*Pounds*
1. Silage made from normal corn	36.0	14.6
2. Silage made from normal corn, ears removed	32.0	8.2
3. Silage made from normal corn, ears from second lot added,	40.5	17.6

Thoroughness of Packing.—The thoroughness of packing is clearly a factor in determining the weight of silage when filling is completed. Thorough tramping and packing results in a more complete expulsion of the air and, consequently, more weight to a given volume. The effect is most pronounced in the upper layers.

Rate of Filling.—The time occupied in filling also influences the weight of silage when filling is completed, and for some time after. Silage settles slowly, and rapid filling, by allowing less time for the air to escape, results in a smaller tonnage in a given space than is the case when more time is occupied in filling. For this reason, when it is desired to utilize the full capacity of a silo, it is first filled, then allowed to settle two days or more, and refilled.

Diameter of the Silo.—The weight of silage per cubic foot increases with the diameter of the silo. King first observed this and Chase made a similar observation. Determinations at the Kansas and Missouri experiment stations showed 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 had been 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. Darnell's investigations[1] also showed that the weight per cubic foot gradually increased from the wall to the center.

In 68 comparisons made at the Missouri station, the average weight per cubic foot at the center was 43.4 pounds, and at the wall, 40.5 pounds. In a silo 16 feet in diameter, the weight of a layer of silage one foot deep was found to be approximately 95 percent of the weight in the center. It is readily seen from these facts, that in a small silo where the wall surface is large in proportion to the volume, the average weight of silage will be somewhat less than in a silo of large diameter.

The cause of this variation in weight between the silage at the wall and at the center is probably friction with the wall, although some explain it by assuming that the silage near the center was tramped more during filling. This is probably not true for the investigations reported in this bulletin, as two men tramped the silage and special care was taken to tramp the silage along the wall.

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[1]Darnell, A. L. Silage investigations. Thesis (unpublished MS) for the degree of master of arts. Univ. of Mo. 1916.

FINENESS OF CUTTING

The effect of fineness of cutting on the weight per cubic foot was tested by dividing a silo into two parts by means of woven wire fencing. In one part, corn cut into lengths of three-quarters of an inch, was placed; and in the other, corn cut in one and one-half inch lengths. The filling of the silo was completed in the ordinary manner. Weights per cubic foot of both lots were determined and found to be exactly the same; namely, 36.5 pounds per cubic foot. In this case, at least, the length of the cuttings had no effect on the weight of the silage.

ESTIMATING WEIGHTS OF SILAGE WHEN FILLING IS COMPLETED

It has been pointed out that there are two distinct conditions under which it is desirable to estimate the weight of silage and that no single table will apply to both. These conditions arise: (1) When filling is completed, and (2) when silage is fully settled.

The data presented here do not justify any attempt to formulate a table to replace that published by the Nebraska station for estimating the amount of silage at the time filling is completed. 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, the silo then being refilled. A portion of the Chase table,[1] with the elimination of some of the fractions, is reproduced in Table V.

In estimating the weight of silage by this table, it is recommended that if the corn is unusually dry, 10 percent of the total weight be deducted. If the corn is dry and very little grain is present, deduct 15 percent. If the corn is average and the silo is filled rapidly and no time allowed for settling deduct 10 percent.

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[1]Chase, L. W. Measuring silage and capacity of silos. Nebr. Agr. Expt. Sta. Cir. 1. Table 2, pp. 5-6. 1917.

TABLE V.—ESTIMATED TONNAGE OF SILAGE AT THE TIME FILLING IS COMPLETED

Depth of silage	Diameter of silo in feet						
	10	12	14	16	18	20	22
Feet	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
1	0.6	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	174.4	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

ESTIMATING WEIGHTS OF SETTLED SILAGE

The weight per cubic foot of settled silage is influenced by the same factors as the weight at the time filling is completed, but not to the same degree with reference to the depth of the silage. This fact is shown in Tables III and VI, in which the average weight per cubic foot for varying depths and for all the corn silage studied in this investigation, is given. It will be noted that while there is some increase in weight with depth, this increase is far less than indicated by King's table. In fact, below a depth of 12 to 14 feet, there is but little increase in weight with greater depth.

TABLE VI.—AVERAGE WEIGHT PER CUBIC FOOT OF SETTLED SILAGE OF VARIOUS DEPTHS

(A comparison of King's table with the results obtained from 25 silos filled with corn)

Depth of silage	Number of silos represented	Average weight for this depth according to	
		Missouri and Kansas investigations	King's table
Feet		*Pounds*	*Pounds*
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	.....

In the present investigation, only once did the weights at a depth beyond 25 feet approach those given by King. King's maximum figure of 61 pounds to the cubic foot at A depth of 36 feet is clearly impossible, as shown by tests made to determine the specific gravity of the dry matter of silage by means of the water displacement method. The silage used in this test was made from corn in the proper stage of maturity, but in which the proportion of grain to forage was only 10 percent, due to the very unfavorable season. Under normal conditions, the grain represents 30 to 35 percent of the total weight. 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 percent of the weight in the grain, the specific gravity of the dry matter of the silage would be 0.768. Silage contains from 11 to 15 pounds of air-dry matter to the cubic foot. It is clear then, that under no conditions can the weight of silage 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 estimating the weight according to volume.

The moisture content of the silage is the most important factor of all in influencing the weight, as shown in Table III. The feeding value of the silage, however, depends upon the dry matter present, and this is subject to far less variation. The data presented in Table III show this in a striking manner.

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. Silo No. 1, for example, as shown in Table III, averaged 52.2 pounds to the cubic foot, while No. 8 averaged 32.8 pounds. No. 1 had 13.9 pounds of air-dry matter per cubic foot and No. 8, 12.7 pounds. In this case the silage in No. 1 weighed 59 percent more than in No. 8, but the difference in the air-dry matter was only 10 percent.

The proportion of grain to forage is of the same importance in estimating the weight of settled silage as in estimating the weight at the time filling is completed. The amount of packing and the period of filling are of minor importance when the silage is fully settled, although of first importance in determining the weight at the time filling is completed. The diameter of the silo is more important for settled silage than for silage in which settling has not been completed.

Table VII is designed for estimating the weight of settled silage. This table should be used only for silage that has settled at least one month. It 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, 25 feet of silage in a silo 16 feet in diameter is estimated by the table to weight 96.2 tons.

If a portion of the silage has been removed, the best plan is to estimate the tonnage before any was removed, and then the amount removed. The difference should be the amount on hand.

TABLE VII.—ESTIMATED WEIGHTS OF SETTLED SILAGE

Depth of silage	Weight of silage per cubic foot at this depth	Average weight of silage per cubic foot to this depth	Weight of settled silage					
			10-ft. diameter	12-ft. diameter	14-ft. diameter	16-ft. diameter	18-ft. diameter	20-ft. diameter
Feet	*Pounds*	*Pounds*	*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
31	43.0	.....	47.63	68.51	93.40	121.90	154.06	189.94
32	43.0	.....	49.32	70.94	96.71	126.21	159.53	196.19
33	43.0	.....	51.01	73.37	100.02	130.52	165.00	202.44
34	43.0	.....	52.70	75.80	103.33	134.83	170.47	208.69
35	43.0	.....	54.39	78.23	106.64	139.14	175.94	214.94
36	43.0	.....	56.08	80.66	109.95	143.45	181.41	221.19
37	43.0	.....	57.77	83.09	113.26	147.76	186.88	227.44
38	43.0	.....	59.46	85.52	116.57	152.07	192.35	233.69
39	43.0	.....	61.15	87.95	119.88	156.38	197.82	239.94
40	43.0	.....	62.84	90.38	123.19	160.69	203.29	246.19
41	43.0	.....	64.53	92.81	126.50	165.00	208.76	252.44
42	43.0	.....	66.22	95.24	129.81	169.31	214.23	258.69
43	43.0	.....	67.91	97.67	133.12	173.62	219.70	264.94
44	43.0	.....	69.60	100.10	136.43	177.93	225.17	271.19
45	43.0	.....	71.29	102.53	139.74	182.24	230.64	277.44

As shown in Table VII, which is based upon all data available, the increase in theweight per cubic foot from a depth of 25 to 30 feet is one pound. In view of this very small increase, it is believed the fairest plan is to assume a constant

weight of silage beyond 30 feet in depth. The weight assumed is 43 pounds per cubic foot. By this plan the table is extended to 45 feet in depth. The weight of each one-foot layer below a depth of 30 feet is as follows:

DIAMETER OF SILO	WEIGHT OF EACH ONE-FOOT LAYER OF SILAGE
10 feet	1.69 tons
12 "	2.43 "
14 "	3.31 "
16 "	4.31 "
18 "	5.47 "
20 "	6.26 "

It should be kept in mind that in using this table it represents average conditions in Kansas and Missouri. In more northern latitudes where the proportion of grain is higher, the weight would be somewhat higher, while in the south where the proportion of grain is less, 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, as for example, in the milk stage, or at the beginning of the dough stage, add 10 to 15 percent to the weights as given in the table. (2) If the grain is unusually heavy in proportion to the stalk, add 5 to 10 percent to the figures as found by the table. (3) If the corn is past the usual stage of maturity and clearly contains less water than usual, deduct 10 to 15 percent. (4) If very little or no grain is present, deduct 10 percent.

ESTIMATING WEIGHTS OF SWEET SORGHUM AND OF KAFIR SILAGE

The increasing use of sweet sorghum and kafir silage raises the question as to the weight of silage from these crops. Data from the Kansas Agricultural Experiment Station are available for four silos. Unfortunately these data do not cover the complete contents of the silos. In one, the depth included was from 17 to 48 feet, and in another, from 1 to 16 feet only.

The air-dry content of the samples was found to vary from 33 to 38 percent, which is normal for silage made from sorghum in the proper stage of maturity. The sorghum from which this silage was made was quite well matured, the seeds being 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 are also available for the weights of kafir in three silos, in one to a depth of 45 feet.

The available data relating to the weights of silage from these crops as compared with corn are given in Table VIII. It will be noted that the sorghum silage weighed less than the corn up to a depth of 15 feet, and more than corn at greater depths. This inconsistency is to be attributed to the limited amount of data rather than greater increase in weight of the sorghum as compared with corn. 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.

TABLE VIII.—COMPARISON OF THE WEIGHTS OF CORN, OF SWEET SORGHUM, AND OF KAFIR SILAGE

Depth of silage	Average weight per cubic foot		
	Corn	Sweet sorghum	Kafir
Feet	*Pounds*	*Pounds*	*Pounds*
6 to 10	36.6	30.4	34.6
11 to 15	39.2	34.0	34.7
16 to 20	40.6	40.8	36.6
21 to 25	41.6	42.0	38.0
26 to 30	42.2	44.0	39.6

In view of the slight variation in weights of silage of the three crops—corn, sweet sorghum, and kafir—and the limited data, it seems advisable to estimate the tonnage of sweet sorghum or kafir with the same table as used for corn.