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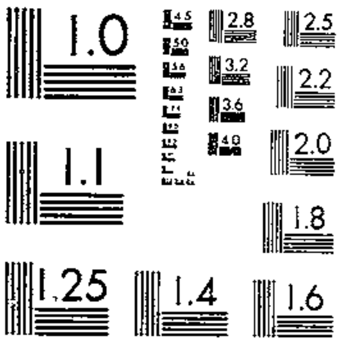

MICROCOPY RESOLUTION TEST CHART
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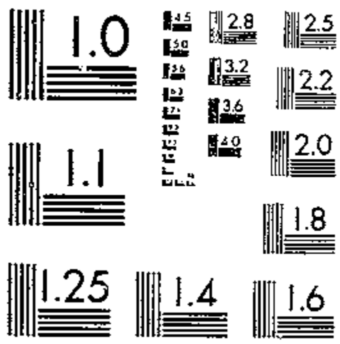

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RELATION OF KERNEL DENSITY TO TABLE AND CANNING QUALITY IN DIFFERENT VARIETIES OF MAIZE

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INTRODUCTION

The production of canned corn of the highest quality calls for a thorough understanding of the factors which determine the quality of the raw corn from which the product is manufactured. It is likewise essential that those interested in the development of more desirable strains have as complete knowledge as possible of the physical and chemical characteristics which give to the existing varieties their distinctive properties.

For a number of years the writers have been endeavoring to aid in the accumulation of needed information on this subject, and in a series of earlier papers (*8, 9, 16*)[1] the results of some of this work have been set forth. It has been shown that among the factors determining quality in sweet corn (*9*) the nature, amount, and relative proportions of the different polysaccharides present in the kernel are of great importance. These constituents, together with the moisture with which they are intimately associated, determine the consistency of the kernel contents and have a direct influence on the smoothness or creaminess of the canned product. Since these polysaccharide and moisture relations vary with the degree of maturity of the kernel and also with the variety of corn, it would appear that the specific gravity of the kernels, which is in a measure an index to these relations, might be of practical significance not only in determining when corn has reached the proper stage of maturity for canning but

[1] Reference is made by italic numbers in parentheses to "Literature cited," p. 14.

also in the development of more desirable strains through breeding and selection.

The work of Burton (*5*) on specific gravity as a means of determining the maturity of sweet corn for canning and the more recent findings of Hoffman (*13*) that evenness of maturity of sweet corn may be secured through careful grading of the seed prompted the present study. It is hoped that the data herein presented may be of some help in the solution of the sweet-corn problems.

The specific gravity of seeds and its relation to the performance of the crops grown therefrom has been the subject of numerous investigations. Its significance has been variously estimated. The early workers cited by Wolffenstein (*26*)[2] found that the heaviest seeds produced the best crops, but Wollny (*28*), working some 20 years later with rye, rape, and peas, concluded that the specific gravity exerted no marked influence on yields. The findings of Sanborn (*20*) with wheat were inconclusive. Hicks and Dabney (*12*), working with soy beans, peas, beans, barley, radish, kafir corn, cane, vetch, rye, sweet peas, and oats, reported best results from heavy seeds, and Degrully (*10*), reporting the work of Garola and Bourgne on barley and maize, concluded that the selection of seed by its density was valuable as a means of increasing crop yields.

Clark (*6*), in studies on the value of specific gravity as a means of more accurate seed selection with grape, mustard, timothy, clover, peas, Swedish turnip, peppers, carrots, cauliflower, cabbage, and eggplant, found a definite correlation between specific gravity and seed germination, seeds of the highest specific gravity, or in the case of the oil-bearing seeds those of intermediate specific gravity, showing the highest percentage of germination. Snyder (*24*), working with wheat, oats, and barley, found that heavyweight seeds have more vitality and produce more vigorous plants. Lill (*15*) reported that kernels of wheat having the greatest density germinated best. He found that germination was independent of the size of the kernel but was directly correlated with its density. Kiesselbach and Helm (*14*), while noting some slight difference between the yields from light and heavy seeds in small-grain crops, concluded that little of practical value is to be gained through grading seed for weight. Renich (*18*) found that bean seedlings from seed of high specific gravity grew more rapidly and produced more vigorous plants than those from seed of low specific gravity. According to Yokoi (*29*) the selection of seeds by specific-gravity methods has been practiced in China and Japan for more than 250 years.

This brief review of the findings of various workers on the relation of specific gravity of seeds to the behavior of the plants derived therefrom, while incomplete, indicates rather clearly that the density of seeds is worthy of careful consideration when studies on improvement are being conducted. Its real significance is not clear from the experimental data cited, because of uncertainty as to the purity of strain of the various seeds tested; and the opinion of Carleton (see discussion of paper by Montgomery, *17*) that differences in the behavior of seeds from a given source may be due to their hybrid character is worthy of serious thought. In all the work so far reported no one seems to

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[2] Original papers not available.

have given much attention to the relation of specific gravity of the seeds studied to their suitability for various uses. With respect to sweet corn, at least, information of this sort seems particularly desirable. In the discussion of experimental findings which follows, the significance of certain differences in the specific gravity of both the developing and the mature seeds of different varieties of maize will be pointed out.

METHODS

Ten varieties of corn, representing the sweet, dent, flour, flint, and waxy types, were selected for the study of the specific gravity of the developing kernels. These were grown at the Arlington Experiment Farm near Rosslyn, Va., during the season of 1925. The dates of planting were so arranged that the ears of the various types developed during the warm part of the summer, and the rate at which the kernels matured was accordingly rapid.[3] Records were kept of the silking date of each ear. Samples of kernels were taken at 5-day age intervals from ears between the ages of 10 and 40 days, considering the date of silking at the starting point in the development of the ear. In all cases the kernels were carefully removed whole and the specific gravity determinations made immediately. The size of the sample varied with the degree of maturity of the corn. Of the very young corn, 30 to 40 grams were used, and of the more mature, 70 to 80 grams. Care was taken in all cases to secure representative samples.

From the time that the corn was at the 15-day stage, canning tests were made at 5-day intervals up to and including the 30-day stage. This served as a basis for correlating the specific gravity of the corn with the quality of the canned product.

For the study of the density of fully matured seed, samples were obtained of numerous varieties of the different types of corn from various sources. Some were from corn grown at the Arlington Experiment Farm; several varieties were supplied by the Office of Cereal Crops and Diseases of the Bureau of Plant Industry, including Cuzco, which was imported from Peru; and the remainder were secured from commercial seedsmen in various parts of the country.

The density was measured by determining the specific gravity of the kernels. These determinations were made by the pycnometer method suggested by Wolffenstein (*27*), which consisted in measuring the volume of a weighed sample of the seeds to be tested. The volume was measured in a burette containing light paraffin oil.

There is more or less inaccuracy in the various methods used for the determination of specific gravity in seeds, due to the absorption of the liquids in which the seeds are immersed and to adhering bubbles of air. Paraffin oil is absorbed to only a slight extent, however, and in these tests an effort was made to eliminate bubbles of air as far as possible by gentle agitation of the burette. Very concordant results were obtained in this way. The chief objection to the use of paraffin oil is its high coefficient of expansion, which means

[3] The development of the corn under these conditions was considerably more rapid than would have been the case in a cooler climate or at the same place later in the season, as shown by earlier work (*16*), with correspondingly rapid changes in the specific-gravity readings.

that where volume measurements are to be made there must be careful temperature control. In the present case effort was made to keep the temperature as nearly constant as possible.

EXPERIMENTAL RESULTS

SPECIFIC GRAVITY AND MOISTURE TESTS

Because of the wide variation in the physical characteristics of the different types of corn, the specific gravity tests upon the developing kernels were made from ears of the sweet, dent, flint, flour, and waxy types. The results of these tests are presented in Table 1.

TABLE 1.—*Specific gravity of maize of different varieties at different ages of the grains*

Age of grains from date of silking (in days)	Specific gravity of maize of—									
	Sweet type			Dent type		Flour type		Flint type		Waxy type—waxy maize
	Golden Bantam	Stowells Evergreen	Guatemalan	Early Adams	Boone County White	Yellow Assiniboine	Mandan White	Longfellow	Rhode Island White	
10	1.008	0.934	0.992	1.005	0.990			1.003	1.010	1.037
15	1.042	1.026	1.054	1.020	1.032	1.044	1.048	1.041	1.051	1.069
20	1.071	1.047	1.078	1.068	1.068	1.114	1.087	1.090	1.060	1.120
25	1.102	1.095		1.121	1.112	1.130	1.126	1.132	1.109	1.165
30	1.120	[illegible]	1.148	1.133	1.165	1.164	1.160	1.195	1.186	1.202
35	1.152	1.214	1.169	1.179	1.180	1.172		1.213	1.220	1.230
40	1.162	1.121	1.180		1.221	1.195	1.175	1.230	1.241	1.240

It is observed that in all varieties, regardless of type, the specific gravity increased as development progressed and maturity was approached. The very young kernels had a low specific gravity and in some cases were found to be even lighter than water. As maturity was approached, however, the kernels became quite heavy and in some cases at 40 days of age were approximately one and one-fourth times as heavy as water.

At the 10-day stage there was very little variation in the specific gravity of any of the varieties, regardless of type. Significant differences began to appear at the 20-day stage, and in general these became more marked as complete maturity was approached. At the 30, 35, and 40 day stages striking differences were recorded. Stowells Evergreen, of the sweet type, showed the lowest density of any of the corns studied, while the waxy maize and the flint varieties showed the highest. Golden Bantam and the Guatemalan late sweet corn had densities slightly lower than varieties of the dent and flour groups, which held an intermediate position.

Figure 1, showing curves for Stowells Evergreen (sweet), Boone County White (dent), and Longfellow (flint), illustrates these differences.

That there is a correlation between the moisture content of the corn of different varieties and its specific gravity is apparent from a comparison of the figures in Tables 1 and 2, which show that in all cases as moisture decreases the specific gravity increases and vice versa. The moisture and sugar determinations, shown in Table 2, were made upon separate samples from the same material and were, of course, subject to sampling error.

The determination of moisture was made by drying 100 grams of the sample to constant weight in the vacuum oven at 80° C. Total sugar was determined as invert sugar according to the methods of the Association of Official Agricultural Chemists.

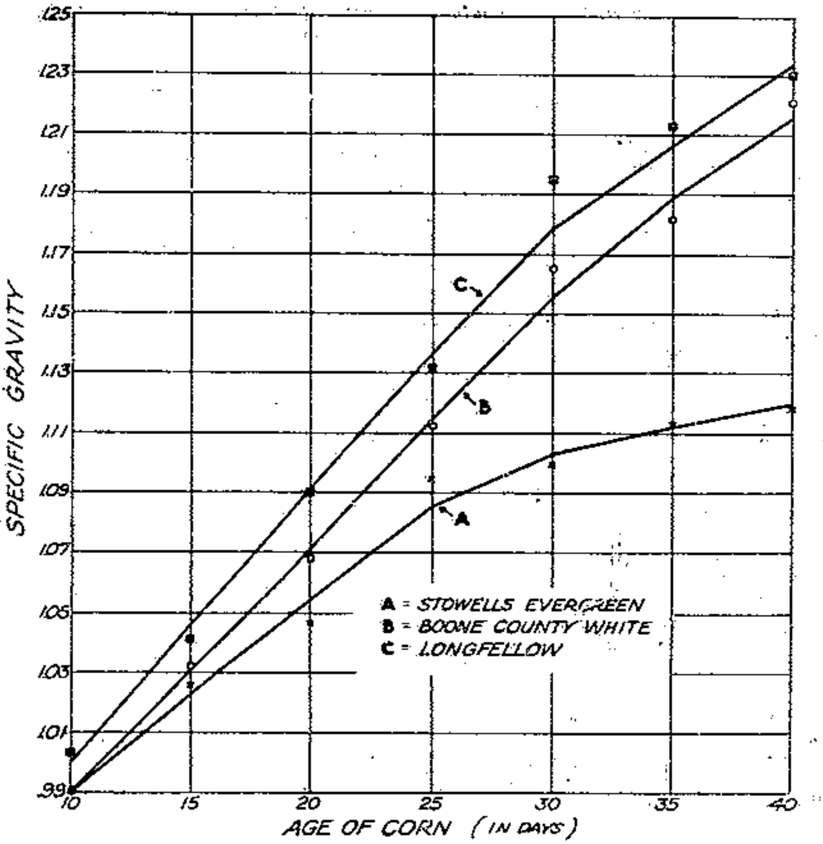

FIG. 1.—Changes in specific gravity of kernels of Stowells Evergreen (sweet), Boone County White (dent), and Longfellow (flint) corn during the development of the ears.

CANNING TESTS

One would expect that such differences in density as have been shown to occur in these varieties would have a direct influence on the table quality of corn, and the canning tests made in the course of these studies showed this to be the case. The product derived from young, immature corn, which, as has been shown, was low in specific gravity and high in moisture content, was "sloppy" in consistency and lacking in that creamy texture that characterizes canned corn of high quality. As development proceeded and maturity was approached, accompanied, as shown, by a corresponding increase in the specific gravity of the kernels, the product became progressively heavier in consistency. Generally in those varieties having a high density the portions of kernels found in the canned product were hard and the contents of the can heavy in consistency. The nature of the polysaccharides present, however, is of very great importance in this connection, as has been shown by the writers in an earlier paper (*9*).

TABLE 2.—*Moisture and sugar content of maize of different varieties at different stages of maturity*

Age of grains from date of silking	Sweet type						Dent type			
	Golden Bantam		Stowells Evergreen		Guatemalan		Early Adams		Boone County White	
	Moisture	Total sugar as invert sugar	Moisture	Total sugar as invert sugar	Moisture	Total sugar as invert sugar	Moisture	Total sugar as invert sugar	Moisture	Total sugar as invert sugar
Days	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
10	89.86	3.74	89.26	4.39	88.77	5.31	89.44	4.31	89.60	4.28
15	83.85	3.95	83.05	6.51	79.73	5.51	81.63	5.16	86.44	5.84
20	75.76	6.91	77.95	4.45	70.61	3.82	76.09	3.05	80.83	4.02
25	65.64	5.45	72.30	3.06	63.18	2.55	67.73	2.41	73.45	3.52
30	58.73	3.35	67.82	2.78	55.74	1.80	57.48	1.85	65.63	2.79
35	53.80		66.10		51.23		51.75			
40	40.84		62.43		47.79		40.63			

Age of grains from date of silking	Flour type				Flint type				Waxy type—waxy maize	
	Yellow Assiniboine		Mandan White		Longfellow		Rhode Island White			
	Moisture	Total sugar as invert sugar	Moisture	Total sugar as invert sugar	Moisture	Total sugar as invert sugar	Moisture	Total sugar as invert sugar	Moisture	Total sugar as invert sugar
Days	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
10	87.82	5.08	88.67	5.10	88.32	4.16	88.94	4.37	88.94	5.31
15	78.03	5.20	77.93	4.35	83.13	4.19	82.92	5.45	82.92	5.51
20	65.14	2.91	62.32	3.08	74.73	3.82	72.14	3.44	72.14	3.86
25	57.35	1.45	60.69	1.66	59.10	2.73	59.40	3.20	59.40	2.65
30	51.25	1.35	47.60	1.25	45.98	1.79	49.00	2.24	49.00	1.60
35	44.10				42.67		40.76		41.84	
40	37.75		41.57		38.10		36.84		36.42	

Other factors were found to be of more importance in determining the table quality of the green corn, but the density or compactness of the endosperm, as measured by its specific gravity, had an important bearing on the quality of the product, particularly with respect to its texture. The preference which is universally shown for the sweet varieties for table purposes is in part due to their low density.

In the very early stages of development the specific gravity of all the varieties was low, and the endosperm was soft in character. As growth proceeded the density increased, the rate of increase varying with the different varieties. In the case of the flint, flour, and waxy types the changes were very rapid, and the high density, coupled with the great toughness of the pericarp, made them unsuitable for table use at stages of maturity which otherwise would have made them acceptable. In the late stages of maturity all types of corn became too dense and hard to yield a palatable product.

It appears from the tests that corn having a specific gravity of 1.05 to 1.08 is in the best condition for table use.

Significant differences in specific gravity are noted, even among the varieties of the sweet type. Stowells Evergreen, characteristically, has a low specific gravity throughout the entire period of growth. Its kernels are large and but loosely filled with starch and dextrin. The Guatemalan has smaller kernels and a more compact endosperm, which is noted even in the very early stages of growth. Golden Bantam holds an intermediate position. These differences are reflected to some extent in the table quality of the varieties. The Guatemalan and Golden Bantam varieties become too hard for table use at a younger age than Stowells Evergreen. While there are other factors to be considered, it seems evident that the quality of corn expressed by the term "hardness," when applied either to a stage of maturity or to a particular variety or type of corn is closely associated with the density.

SPECIFIC GRAVITY OF DRY AND SOAKED KERNELS

Inasmuch as the foregoing data were available, it seemed desirable to determine whether the specific gravity of the dry seeds bore any relation to the specific gravity of the developing kernel, for if such a relationship was found to exist a ready means of determining what would be the quality of the corn developing from any particular lot of seed would be at hand.

Preliminary tests on the air-dry seeds of flint, dent, and sweet corn types showed differences of doubtful significance. Other tests were then made on seeds of the same varieties after they had been soaked in water, and the results are presented in Table 3.

TABLE 3.—*Specific gravity of seeds of Stowells Evergreen (sweet), Golden Bantam (sweet), Boone County White (dent), Longfellow (flint), and waxy maize, after they had been soaked in water 15 days*

Sample No.	Specific gravity of—				
	Stowells Evergreen	Golden Bantam	Boone County White	Longfellow	Waxy maize
1	1.081	1.138	1.201	1.226	1.205
2	1.070	1.126	1.190	1.218	1.214
3	1.070	1.132	1.197	1.240	1.210
4	1.095	1.145	1.211	1.218	1.223
5	1.090	1.124	1.195	1.227	1.265
Average	1.081	1.133	1.199	1.226	1.223

It will be noted on comparing Table 3 with Table 1 that for differences in the specific gravity of the soaked seeds there are, in general, corresponding differences in the specific gravity of the developing kernels, particularly in the late stages of maturity.

The above-mentioned specific-gravity tests upon dry and soaked seeds showed that the seeds of maize differ tremendously in their capacity for water absorption. The tests indicated that the specific gravity of the soaked seeds might be of practical value in predicting the suitability of the different strains of corn for table use in the green condition. Further data on this point seemed desirable, as they might possibly be used to explain the results obtained with the developing kernels and thereby add to the value of those results.

For the purpose of obtaining more information on the water-absorption capacity, the degree of swelling, and the specific gravity both before and after the seeds had been soaked in water, a quantity of seeds of a large number of varieties was obtained. This collection included 15 varieties of such distinct types as sweet, dent, flint, flour, pop, and waxy maize. Specific-gravity determinations were made on the air-dry seeds and on seeds after they had been soaked in distilled water. The water absorbed was determined by immersing a weighed quantity of the seeds in distilled water and placing them in a refrigerated chamber where the temperature ranged from 0° to 5° C. At the end of 21 days they were removed from the water, pressed between towels to remove the water adhering to the surface of the kernels, and then weighed immediately. The volume was measured and the specific gravity calculated. Table 4 shows the results of these tests.

SPECIFIC GRAVITY OF AIR-DRY SEEDS

Striking differences were noted in the specific gravity of the air-dry seeds of certain groups, some having an average value approximately one-third heavier than water, whereas others averaged but little heavier than water. The kernels of the pop varieties averaged the densest of all those studied, though the seeds of the one strain of waxy maize were nearly as dense. The specific gravity of the flint varieties differed considerably, but averaged somewhat less than the pop corns. The kernels of the dent and sweet varieties were also somewhat less dense than those of the pop-corn type. Collins and Kempton (7) found that the specific gravity of the air-dry kernels of the sweet, waxy, and flinty types was the same.

The varieties of the flour type had kernels strikingly lower in specific gravity than those of any other type. In the dry condition the seeds of this type have a soft, loose structure and contain considerable air. The low specific gravity and the small quantity of water-soluble material which they contain seem to account for the floury characteristic.

The sweet varieties which had a low specific gravity during the development period of the kernels are seen to have had a fairly high value when air dry.

By comparing the figures in Table 4 with those in Table 1 it is observed that there is no general relationship between the specific gravity of the air-dry seeds and of the developing kernels of the same varieties; hence one can not predict the specific gravity of the developing kernels from the specific gravity of the air-dry seeds.

TABLE 4.—*Average volume, average weight, and specific gravity of the kernels of different varieties of corn both before and after they had been soaked in distilled water*

Variety	Type of maize	Air-dry grains			Grains after they had soaked 21 days in distilled water				
		Average volume per kernel	Average weight per kernel	Specific gravity	Average volume per kernel	Average weight per kernel	Specific gravity	Swelling	Water absorbed
		C. c.	*Grams*		*C. c.*	*Grams*		*Per cent*	*Per cent*
Stowells Evergreen	Sweet	0.1400	0.1710	1.221	0.4234	0.4589	1.079	202.4	167.2
Narrow-grained Evergreen	do	.1406	.1704	1.212	.3224	.3500	1.104	129.2	108.9
Golden Bantam	do	.1873	.2332	1.245	.4335	.4007	1.132	131.3	110.3
Guatemalan	do	.1447	.1860	1.286	.3487	.3911	1.128	139.4	110.3
Kellys Hybrid	do	.1771	.2196	1.240	.4061	.4347	1.070	129.3	97.9
Charlevoix	do	.1237	.1490	1.204	.3230	.3518	1.089	161.1	136.1
Howling Mob	do	.1877	.2397	1.277	.3987	.4674	1.172	112.4	95.0
Country Gentleman	do	.0898	.1122	1.250	.2225	.2470	1.110	147.8	120.1
Bantam Evergreen	do	.1922	.2397	1.247	.4380	.4939	1.127	127.8	106.1
Golden Cream	do	.1442	.1708	1.226	.3039	.3418	1.125	110.7	93.3
Golden Giant	do	.1907	.2301	1.238	.4243	.4782	1.127	122.5	102.5
Potters Excelsior	do	.2138	.2591	1.212	.4317	.5020	1.163	101.9	93.8
Mammoth Sugar	do	.2059	.2503	1.215	.4545	.4985	1.097	120.7	99.2
Early Adams	Dent	.2331	.2799	1.201	.4160	.4896	1.177	78.4	74.9
Boone County White	do	.3168	.3845	1.214	.5521	.6606	1.197	74.4	71.8
Hoffmans	do	.3165	.3032	1.242	.5228	.6281	1.201	65.2	59.8
Square Deal	do	.1770	.2112	1.193	.2865	.3399	1.185	61.8	60.8
Hastings Prolific	do	.1792	.2389	1.333	.2814	.3458	1.229	57.0	44.5
Hickory King	do	.4129	.5117	1.239	.6454	.8019	1.242	56.1	56.7
Yellow Creole [1]	do	.3073	.3826	1.245	.4709	.5796	1.231	53.2	51.5
Improved Golden	do	.2741	.3302	1.227	.4477	.5429	1.211	63.3	61.5
Reids Yellow	do	.2795	.3413	1.221	.4702	.5529	1.176	68.2	62.0
Tennessee Red Cob	do	.2695	.3345	1.241	.4631	.5597	1.208	71.8	67.1
Ivory King	Flour	.2168	.2308	1.065	.3454	.4004	1.156	59.5	73.4
Yellow Assiniboine	do	.2322	.2503	1.078	.3570	.4073	1.141	54.1	62.7
Mandan White	do	.2551	.2787	1.092	.4068	.4865	1.195	59.5	74.6
Cuzco (yellow)	do	.9294	1.0228	1.100	1.4120	1.6750	1.186	51.8	63.7
Cuzco (white)	do	1.1150	1.1330	1.016	1.6500	1.8720	1.134	48.0	65.3
Cuban Yellow	Flint	.2066	.2662	1.288	.3210	.3922	1.222	55.3	47.3
Rainbow	do	.2430	.2918	1.198	.3686	.4407	1.195	51.1	51.0
Squaw [1]	do	.2190	.2691	1.229	.3580	.4324	1.208	63.5	60.7
Stickney	do	.3250	.3830	1.178	.4885	.5782	1.184	50.3	50.9
Rhode Island White	do	.2806	.3612	1.287	.4157	.5338	1.284	48.1	47.8
Longfellow	do	.3090	.3915	1.267	.4673	.5794	1.240	51.2	48.0
Leaming Improved [2]	do	.2610	.3272	1.253	.3968	.4967	1.251	52.0	51.8
King Philip	do	.2390	.2937	1.229	.3737	.4400	1.177	56.3	49.8
Sanford White	do	.2850	.3599	1.258	.4213	.5196	1.233	47.3	44.3
Pride of the North [2]	do	.2252	.2827	1.255	.3426	.4228	1.234	52.2	49.4
Early Yellow Canada	do	.2907	.3554	1.222	.4350	.5322	1.223	49.7	49.6
Red Beauty	Pop	.0633	.0805	1.272	.1081	.1296	1.199	70.8	61.0
White Rice	do	.0786	.1020	1.298	.1223	.1508	1.233	55.5	47.8
New Tom Thumb	do	.0523	.0693	1.325	.0848	.1046	1.233	62.1	50.9
Baby Golden	do	.0665	.0849	1.274	.0970	.1206	1.243	45.6	42.0
Waxy maize	Waxy	.1209	.1620	1.277	.2459	.2876	1.170	93.7	77.5

[1] These varieties were semiflint in character.
[2] These varieties, while ordinarily classed as dent corns, were flinty in character in these samples.

SPECIFIC GRAVITY OF SEEDS SOAKED IN DISTILLED WATER

The specific gravity of the seeds soaked in distilled water was usually less than that of the air-dry seeds, though the seeds of the flour type were an exception to the rule, being more dense after they had been soaked than before. The flint, pop, and waxy types had a high specific gravity and the sweet varieties a low, the flour and dent types held an intermediate position. These differences in the specific gravity of the soaked seeds corresponded in a general way to the differences observed in the developing kernels.

Considering these data and the figures secured through an examination of the kernels of different lots of the same varieties, shown in

Table 3, and other observations not recorded here, the conclusion seems warranted that, when grown under favorable conditions, each variety, and probably every strain, has a characteristic specific gravity. It was apparent also from a comparison of the specific-gravity data on the 13 varieties of sweet corn with the behavior of these varieties when canned that the specific gravity of the soaked seeds was correlated to a certain extent with the consistency of their canned product. The high specific gravity of the developing kernels of the field-corn varieties (see Table 1) is seen to be paralleled by the high specific gravity of their soaked seeds, which is correlated with the hardness of the corn when used for table purposes.

SWELLING POWER OF SEEDS

The question naturally arises as to the explanation of the differences in the specific gravity of corn before and after soaking in water. This explanation is to be found in the swelling power of the seeds and their water-absorbing capacity.

In the third column of Table 4 is shown the average volume per kernel of the different varieties before they had been soaked, and in the sixth column the average volume after they had been soaked. A wide variation is noted in the volume of the seeds, White Cuzco, one of the flour corns, for instance, having approximately 20 times the volume of New Tom Thumb, one of the pop corns. The volume is always greater, of course, after they have been soaked in water, and the percentage increase in volume for the different varieties is shown in the ninth column. It is observed that the swelling power of the sweet varieties was much greater than that of any other type of maize. Stowells Evergreen increased in volume more than 200 per cent when soaked in water. No outstanding differences are seen in the percentage of swelling among the corns of the other types, though waxy maize and the dent varieties averaged a little higher than the others. Considerable variation is noted among the varieties within the different types.

In reviewing the data presented in Table 4 it appears significant that only those varieties whose dry kernels have a high swelling capacity are well suited for table use in the green condition, as has been shown by repeated experiments.

WATER-ABSORBING CAPACITY

In the fourth column of Table 4 is shown the average weight per kernel of the different varieties before they had been soaked, and in the seventh column the same after they had been soaked. The percentage increase in weight, or the quantity of water absorbed, is shown in the last column. The sweet varieties had outstandingly greater water-absorbing capacity than those of any other type. One of them absorbed more than 150 per cent of its air-dry weight, and none absorbed less than 90 per cent. Among the other types only one was found that absorbed more than 75 per cent, while many of them absorbed less than 50 per cent.

It was found that when the percentage of increase in volume was greater than the percentage of increase in weight the specific gravity decreased, and when the weight of water absorbed was greater than the percentage of increase in volume the specific gravity increased.

In the endosperm of the sweet corn the cells contain a comparatively small amount of insoluble material and a comparatively large amount of water-soluble material, such as dextrin (*8*, *9*). As the corn matures, this water-soluble material dries and shrinks to a hard, translucent mass which contains but little air. When soaked in water this swells and expands correspondingly more than it absorbs water; hence the specific gravity decreases during the soaking. In the flour corns, on the other hand, there is comparatively little water-soluble material and a large amount of granular insoluble material which can not shrink so as to cement the mass together on drying; hence, much space between the particles is filled with air, and the flour corns have a low specific gravity when dry. When the flour corns are soaked in water the air is partially or completely dissolved in the water, and the amount of swelling is proportionately less than the volume of water absorbed. The specific gravity thus increases during the soaking.

In the flint corns there is a large amount of insoluble material (*9*), but this is so closely packed into the endosperm that the cells are almost completely filled and comparatively little water can be absorbed and comparatively little swelling can occur. Hence they have a high specific gravity both before and after being soaked in water.

The present data point to a very important relation between swelling power and water-absorbing capacity of the dry corn and its suitability for table use in the green condition as well as for food products manufactured from the dry grain.

WRINKLEDNESS IN SWEET CORN

Since in the canning tests here reported and in the data presented in earlier papers (*8*, *9*), no smooth-seeded varieties were found to be well suited for canning purposes, an understanding of the cause of wrinkledness is important.

The chief characteristic by which sweet corn is distinguished from other types is the wrinkled condition of the dry seeds, and this characteristic has been considered as an indication of suitability for table use. In these experiments careful attention was given to the wrinkled character of the seeds employed, whether they were smooth, coarsely wrinkled, or finely wrinkled. Salisbury (*19*) attributed the wrinkled condition to the loss of water by the dextrins and albumins which the kernels contained, and Harper (*11*) considered that sugar, dextrin, and gums were responsible for this condition. While there are probably several factors concerned, the degree of wrinkledness is determined by the character and quantity of the kernel contents, of which the specific gravity is an indication. The presence of a comparatively small amount of granular, insoluble material in the cells with much water-soluble material of such concentration that the density never becomes great until after the maturing seed begins to dry seems to be the condition most favorable for wrinkledness. The presence of colloidal materials of a highly plastic nature, such as dextrin, water-soluble starch, and protein, are more favorable for the production of wrinkledness than other less plastic materials. Wrinkledness is, therefore, a result of the metabolic activity of the endosperm cells. If the transformations are such that the cells are compactly filled with organic solids, little wrinkledness can occur. If chemical equilibrium in the metabolic processes is reached before the accumulating material becomes very dense, a condition favorable to wrinkledness arises. The degree of wrinkledness, or the amount of shrinking, is correlated with the density of the developing kernels, as is shown by the comparative densities of Stowells Evergreen, Golden Bantam, and the Guatemalan varieties. Examination of the dry kernels of these varieties showed Stowells Evergreen to be the most wrinkled while the Guatemalan was least. The density of these varieties is shown in Table 1.

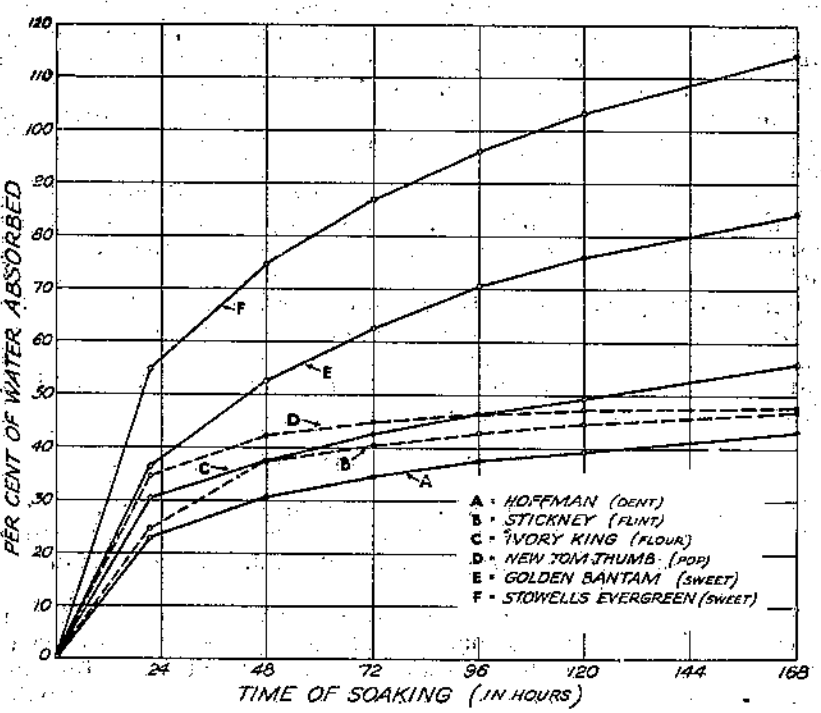

FIG. 2.—Percentage of water absorbed by seeds of different types and varieties of maize when soaked in distilled water for various periods of time

The character of the wrinkledness, such as coarse or fine, is also partly dependent on the density of the kernel.

RATE OF WATER ABSORPTION

The rate of water absorption by the dry seeds of different types of maize is of interest in this connection. A number of workers have given attention to the absorption of water by seeds, among them Brown (*2*, *3*), Atkins (*1*), Schroeder (*21*), Brown and Worley (*4*), Shull (*22*, *23*), and Wolfe (*25*). The rate of absorption, the forces concerned in absorption, and the relation of temperature to the rate and degree of absorption have been studied. In Figure 2 are shown curves illustrating the differences in the rate of water absorption observed in a few varieties during the present investigation.

Stowells Evergreen and Golden Bantam absorbed water at a very much greater rate than the flint, dent, flour, and pop corn varieties, and it is evident that the rate of absorption is correlated with the density of the developing kernel. The size of the kernel is also a factor influencing the rate of water absorption. This is shown by the difference in the curve for New Tom Thumb and Stickney flint varieties. Although absorbing about the same percentage of water, the New Tom Thumb absorbed the greater part during the first day or two. This was undoubtedly due to the small size of the kernel.

FACTORS AFFECTING SPECIFIC GRAVITY AND WATER-ABSORBING CAPACITY

The specific gravity of the air-dry seeds, as well as their water-absorbing capacity, depends upon many factors. The rate and amount of absorption is affected by the temperature, as has been shown by the work of Brown and Worley (*4*). It has been observed that the specific gravity of corn matured in the very late fall is lower than the specific gravity of that developing earlier.

To show the effect on specific gravity of harvesting corn at different periods of development, Stowells Evergreen and Early Adams varieties were harvested 20, 25, and 30 days from the date of silking and allowed to dry. The specific gravity and the water-absorbing capacity of these corns were then determined, and the results are presented in Table 5.

TABLE 5.—*Specific gravity and water absorption of corn of Stowells Evergreen and Early Adams varieties harvested at different ages and allowed to air-dry*

Variety	Age from date of silking	Air-dry grains			Grains after they had soaked 21 days in water				
		Average volume per grain	Average weight per grain	Specific gravity	Average volume per grain	Average weight per grain	Specific gravity	Swelling	Water absorbed
		C. c.	*Grams*		*C. c.*	*Grams*		*Per ct.*	*Per ct.*
Stowells Evergreen.	20 days	0.0605	0.0667	1.102	0.2338	0.2435	1.041	286.4	265.0
	25 days	.1044	.1220	1.169	.3349	.3564	1.064	220.8	192.1
	30 days	.1347	.1690	1.254	.4155	.4518	1.087	208.4	167.3
	Fully matured	.1400	.1710	1.221	.4234	.4569	1.079	202.4	167.2
Early Adams	20 days	.0653	.0681	1.043	.1526	.1678	1.100	133.7	146.4
	25 days	.1305	.1412	1.082	.2874	.3212	1.118	120.2	127.8
	30 days	.1743	.1971	1.131	.3777	.4385	1.161	116.7	122.5
	Fully matured	.2331	.2799	1.201	.4160	.4896	1.177	78.4	74.9

The water-absorbing capacity of the immature air-dry seeds was much greater than that of the fully matured seeds, and the specific gravity of the immature seeds of Early Adams both before and after they had been soaked was quite different from that of the mature kernels. The specific gravity of the mature seeds decreased when the seeds were soaked, but that of the immature seeds increased; thus they behave somewhat like the kernels of flour corn, earlier considered. This is explained by the nature of the carbohydrate present and the density of the kernel. A low specific gravity and greater water-absorption capacity characterize immature or so-called soft corn.

SUMMARY

The density of the developing seeds of maize varies with the stage of maturity and with the type or strain. The fully mature seeds vary with the variety or type, with their moisture content, and with the conditions under which they are grown.

The density of the very immature kernels is low and does not vary greatly with the different varieties. The density constantly increases during development and usually reaches a high value in the mature air-dry seeds.

Except in the very immature stages, the developing seeds of the sweet type have the lowest density of all the types studied. This low density is a factor contributing to those characteristics of sweet corn which make it preferred as a product for table use.

The difference in the density of the mature air-dry seeds of different varieties is often quite marked. Varieties of the pop type have a very high density, whereas those of the floury type have a low density.

When the mature air-dry seeds are soaked in water there is a marked difference in the behavior of varieties in regard to the rate of water absorption and the total quantity imbibed. The amount of swelling which occurs is likewise quite different. The varieties of the sweet type absorb large quantities of water and also swell greatly. Many varieties, particularly of the flinty type, absorb moderate quantities and likewise swell to a moderate degree. Certain varieties, particularly of the flour corns, absorb moderate quantities of water but swell comparatively little. Thus the behavior during the soaking often results in very characteristic and very marked changes in specific gravity. For example, the seeds of the sweet type decrease in specific gravity during the soaking, while varieties of the floury type increase.

The data here presented add materially to an understanding of why sweet corn is usually preferred for table use and help to a certain degree in explaining the wrinkled, flinty, waxy, and floury characters of certain types of maize.

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