A STUDY OF THE FACTORS DETERMINING QUALITY IN SWEET CORN

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INTRODUCTION

The importance of quality in sweet corn as affecting its successful manufacture and sale as a canned product is coming to be more fully appreciated. A thorough understanding, therefore, of just what constitutes quality and what those factors are by which it is affected is desirable.

It is known that seasonal and climatic factors, through their influence on the rate at which the corn develops and matures, play an important part in determining the quality of the canned product. It is apparent also that certain characteristics possessed by sweet corn as distinct from field corn are likewise of very great importance.

Among the various types of corn used as human food a wide variation is known to exist. Earlier investigations on the relation of the variety of corn to the quality of the canned product brought to light fundamental differences in the constitution of sweet and field corns which were reflected directly in the physical appearance and table quality of their canned products. In order, therefore, to gain a better understanding of what constitutes quality, and of the relation of varietal differences to it, the field of the investigations here discussed was extended to include not only the sweet but also representatives of the flint, dent, and flour corns, waxy maize, and other well-known or special types not previously investigated. The results of this study are set forth in the present paper.

To indicate his conception of the probable relationship of the different types of corn, Sturtevant in his taxonomic grouping of the different varieties of corn placed the podded varieties first as the most primitive. Pop, flint, dent, and soft or flour corns in the order named were included in his grouping. He was uncertain as to the relationship of the sweet varieties to the other types. Waxy maize was little known until comparatively recently and hence was not considered in Sturtevant's work.

Whether or not one is justified in assuming any evolutionary relationship between the different types of corn, there are certain physical characteristics that suggest such a relationship. This fact should be kept in mind in the discussion of the present findings.

1 Received for publication Nov. 4, 1926; issued April, 1927.
In the flint corns the endosperm is characterized by a starchy core surrounded by a hard, flinty portion that varies somewhat in thickness in the different varieties. In the dent corns the sides of the kernel are composed of a cornaceous portion, the starchy core being central in location and extending to the tip of the kernel. It is to the shrinkage of this starchy portion that the denting of the kernel is due. In the soft or flour corns little of the tough horny element is present, the contents of the endosperm being made up almost entirely of soft, starchy tissue.

Sweet corn is characterized by a translucent, hard, wrinkled or shriveled endosperm, the shriveling being due apparently to the nature of the polysaccharides contained in it and the manner in which they are laid down. In physical appearance the waxy maize resembles more nearly the corn of the flint varieties, having a hard full kernel. The kernel contents, however, present a waxy appearance when the kernel is split. In chemical composition it more closely resembles the sweet varieties, particularly with respect to the water-soluble portion.

PLAN OF INVESTIGATION

The investigation was carried on during the season of 1925 in the fields and laboratories of the Arlington Experiment Farm, Rosslyn, Va. The location of the test plots and the cultural practices followed in this study were as nearly identical with those of the earlier studies as seasonal conditions would permit. The methods of observation, testing, and analysis also were similar.

Nine varieties were studied during the season: Two flour corns, Mandan White and Yellow Assiniboine, from North Dakota; two flint corns, Longfellow and Rhode Island White, from New England; a variety of late sweet corn, which originated in Guatemala; an unnamed variety of waxy maize obtained from the Office of Cereal Crops and Diseases, Bureau of Plant Industry; Second Early Adams, a dent variety widely used by market gardeners for the roasting-ear trade, and obtained from a local seedsman; and two well-known varieties of sweet corn, Golden Bantam and Stowell’s Evergreen, from Pennsylvania. The two last-named varieties were planted as checks on the others and also to furnish additional data on these two varieties for comparison with similar data accumulated over a period of several years.

With the exception of three varieties, the plantings in the test covered by this discussion were made May 16. Golden Bantam, Stowell’s Evergreen, and Second Early Adams were planted June 26.

To permit of thinning to a uniform stand when the plants were sufficiently well developed, a heavy seeding was made. Standard cultural practices were followed throughout the growing season.

As in previous studies, the rate of development of the corn and the tagging of ears were recorded to facilitate later sampling.

Sampling for chemical analysis, for determination of yields and degree of toughness, as well as for canning tests, was performed as usual.

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Fig. 1.—Climatic or meteorologic conditions under which corn of different varieties was grown at Arlington Experiment Farm, Rosslyn, Va., 1925.
The seasonal climatic conditions under which the corn was grown are shown in Figure 1, which gives the meteorological data for the season of 1925 at the Arlington Experiment Farm.

Two outstanding features mark the season—an unusually long period of summer temperature and a considerable deficiency of rain during the growing season.

During the month of May the temperatures showed sharp fluctuations. On May 23, for instance, the summer temperature of 97° F. was recorded. Within 48 hours the maximum temperature dropped to 54°, a variation of 43°. During the latter part of May the temperature rose steadily, and on the 5th of June reached the highest maximum of the summer. The mean daily temperature for June was, with very few exceptions, above normal. During July it remained close to normal. It was slightly below normal during the latter half of the month and the early part of August. During August the temperature showed only slight variation from normal. Summer temperatures and almost unbroken summer conditions prevailed from June 1 to September 21. The latter part of September and the month of October showed the usual sharp fluctuations in temperature.

As already stated, the rainfall was below normal during the spring and early summer. The rainfall during May was only 60 per cent of normal. June showed the most pronounced shortage, the total for the month being 1.68 inches, or about 36 per cent of normal. In July the rainfall was 68 per cent of normal. Approximately one-half of this rain occurred on July 31. The rainfall for August and September was about normal in total amount, although the period from August 23 to September 13 was almost entirely rainless. October had more than twice its normal rainfall, the total for the month amounting to 5.71 inches. The sunshine for the entire season did not vary far from normal.

In the study of sweet-corn behavior it is important that seasonal conditions be taken into consideration since, as has been shown by the writers in an earlier study,\(^7\) temperature has a profound effect upon the rate at which growth and maturity proceed, and influences to some extent also the relative proportions of the different chemical constituents in the kernel.

While rainfall has no apparent effect on the rate at which maturity advances or on the chemical composition of the corn, it does have a direct influence in determining crop yields. Indirectly, through its effect on soil temperatures, rainfall affects the vital processes in the corn kernels.

No specific effect of sunshine on sweet corn has as yet been discovered.

FLOWERING RECORDS

The flour corns, Mandan White and Yellow Assiniboine, were the first to reach the silking period, and the records of these two varieties were entirely similar. Silks were first observed on July 7, 52 days after planting. The silking continued over a period of approximately two weeks, although in both cases the peak of silking occurred on July 8.

The flint varieties, Rhode Island White and Longfellow, were next to flower. Tasseling began on July 13, and on July 17, 62 days after planting, the first silks appeared. The peak of silking in the Longfellow was reached on July 26 and in Rhode Island White on July 28. Silking extended over a period of about three weeks.

The Guatemalan sweet variety began to tassel on July 20, and the first silks appeared on July 30, 75 days after the date of planting. Silking continued for about four weeks, the nearest approach to a peak occurring on or about August 16.

The plot of waxy maize began tasseling on July 21. The first silks were observed on August 9, 85 days from the date of planting. Silking continued for about three weeks, the peak being reached on August 20.

Second Early Adams, Golden Bantam, and Stowell's Evergreen, planted 41 days later than the varieties just mentioned, came into flower very much later than they would have if planted at the same time as the others. Second Early Adams and Golden Bantam each began tasseling on August 5. Their first silks appeared on August 11, 46 days after planting. Silking records were continued for a period of only two weeks. The peak of silking for Golden Bantam was reached on August 19, and for Second Early Adams August 20.

Stowell's Evergreen began tasseling on August 11. Silking started on August 19, 54 days from the date of planting. Records were discontinued after 17 days of silking, the peak being reached on August 31.

While the last three mentioned varieties were planted later and came to flower at a later date than the other varieties, it is doubtful if the actual length of time required for them to come to flower was very different from what it would have been had they been planted at the same time as the others. This assumption is based primarily on the fact that the temperature of the growing periods of both groups of corn as shown in Figure 1 was remarkably uniform.

The ear and cut corn records made in connection with the experiment under discussion are presented in Table 1.
TABLE 1.—Rate of development of ears of different types and varieties of corn grown at the Arlington Experiment Farm, Rosslyn, Va., 1925

<table>
<thead>
<tr>
<th>Type or variety</th>
<th>Date of sampling</th>
<th>Age in days</th>
<th>Number of ears taken</th>
<th>Average weight of ears in grams</th>
<th>Average weight of shucked ears in grams</th>
<th>Average weight of cut corn per ear in grams</th>
<th>Per cent of husk</th>
<th>Per cent of cob</th>
<th>Per cent of cut corn</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manxliner (flour)</td>
<td>July 10</td>
<td>5</td>
<td>144.6</td>
<td>65.5</td>
<td>44.5</td>
<td>24.6</td>
<td>60.0</td>
<td>40.0</td>
<td>20.0</td>
<td>Very poor pollination.</td>
</tr>
<tr>
<td>Yellow Assiniboine (flour)</td>
<td>July 10</td>
<td>5</td>
<td>144.6</td>
<td>65.5</td>
<td>44.5</td>
<td>24.6</td>
<td>60.0</td>
<td>40.0</td>
<td>20.0</td>
<td>Scanty husks.</td>
</tr>
<tr>
<td>Longfellow (flint)</td>
<td>July 10</td>
<td>5</td>
<td>144.6</td>
<td>65.5</td>
<td>44.5</td>
<td>24.6</td>
<td>60.0</td>
<td>40.0</td>
<td>20.0</td>
<td></td>
</tr>
<tr>
<td>Rhode Island White (flint)</td>
<td>July 10</td>
<td>5</td>
<td>144.6</td>
<td>65.5</td>
<td>44.5</td>
<td>24.6</td>
<td>60.0</td>
<td>40.0</td>
<td>20.0</td>
<td></td>
</tr>
<tr>
<td>Guatemalan (sweet)</td>
<td>July 10</td>
<td>5</td>
<td>144.6</td>
<td>65.5</td>
<td>44.5</td>
<td>24.6</td>
<td>60.0</td>
<td>40.0</td>
<td>20.0</td>
<td></td>
</tr>
<tr>
<td>Second Early Adams (dent)</td>
<td>July 10</td>
<td>5</td>
<td>144.6</td>
<td>65.5</td>
<td>44.5</td>
<td>24.6</td>
<td>60.0</td>
<td>40.0</td>
<td>20.0</td>
<td></td>
</tr>
<tr>
<td>Waxy maize</td>
<td>July 10</td>
<td>5</td>
<td>144.6</td>
<td>65.5</td>
<td>44.5</td>
<td>24.6</td>
<td>60.0</td>
<td>40.0</td>
<td>20.0</td>
<td></td>
</tr>
<tr>
<td>Golden Bantam (sweet)</td>
<td>July 10</td>
<td>5</td>
<td>144.6</td>
<td>65.5</td>
<td>44.5</td>
<td>24.6</td>
<td>60.0</td>
<td>40.0</td>
<td>20.0</td>
<td></td>
</tr>
<tr>
<td>Stowell’s Evergreen (sweet)</td>
<td>July 10</td>
<td>5</td>
<td>144.6</td>
<td>65.5</td>
<td>44.5</td>
<td>24.6</td>
<td>60.0</td>
<td>40.0</td>
<td>20.0</td>
<td></td>
</tr>
</tbody>
</table>
The results of tests of the corns for toughness at different stages of maturity are of considerable interest and are shown in graphic form in Figure 2.

It will be observed that the different varieties formed two distinct groups with respect to toughness: (1) The flour, flint, and waxy varieties, which became extremely tough as maturing proceeded; and (2) the sweet varieties and Second Early Adams, a dent variety, none of which exceeded the 420-gram mark at 30 days of age.

The grouping of the Second Early Adams with the sweet varieties, in respect to tenderness, is of particular interest. This variety is really a field corn belonging to the dent group. In earliness it corresponds closely with Golden Bantam. This fact, together with its relative tenderness, probably accounts for its wide use in the roasting-ear trade.

It is of interest also to compare the toughness curves of the varieties shown in Figure 2 with those of the dent varieties, Boone County White and Reid Yellow Dent, which were presented in a previous paper, and which show that these two varieties were also relatively tender up to 30 days of age. It is by no means certain that all flint, flour, and waxy varieties are extremely tough or that all dents are relatively tender, even though records so far obtained indicate that this is the case.

The significance of the results recorded in Figure 2 will be discussed in another section of this article.

CHEMICAL STUDIES

The chemical constituents of corn, their nature, relative proportions, and physical conditions within the kernel, determine to a very large degree the suitability of any corn for canning purposes. This is particularly true of the carbohydrates. Within this group of substances are to be found those which determine

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Fig. 2.—Degree and rate of increase in toughness of corn of different types and varieties with advancing maturity: A, Mandan White; B, Yellow Assiniboine; C, Waxy maize; D, Rhode Island White; E, Longfellow; F, Guatemalan; G, Stowell’s Evergreen; H, Golden Bantam; I, Second Early Adams; J, Boone County White (from data collected in 1922 and introduced here for comparison)
the natural sweetness of the corn and the consistency and texture of the canned product.

The rôle of the nitrogenous constituents and of the oil of corn in their influence on quality is not known. It is possible that some of the distinctive flavors of corn of the different types and of corn at different stages of maturity are more or less closely associated with these substances. No investigation seems to have been made to determine such a relationship. The experiments covered by this paper did not include such a study. The presence of the distinctive fresh corn flavors and their rate of disappearance in the harvested corn seem to parallel closely the changes in sugar content.

The analytical data here presented, therefore, are concerned primarily with the carbohydrates of corn of the different types under investigation and the changes taking place in them as maturity advances.

It is a common notion that the property of sweetness distinguishes the so-called sweet corns from other types, making them better adapted to canning purposes, and that the accumulation of starch in the kernel is what gives to the corn in the can its desirable creamy consistency and texture. It has been shown by the writers, however, that a relatively high sugar content is not confined to the sweet corns alone, and that the presence of dextrin or dextrinlike compounds in the sweet corns has much to do with the desirable physical properties of their canned product.

Among the different types of corn selected for the experiments here discussed a wide range of conditions, as regards the nature and relative proportions of the different carbohydrates, is known to exist. Waxy maize, for instance, has a very high dextrin content; the flint, flour, and dent varieties not only have high starch contents but the physical condition of the starch in the kernel differs greatly; and among the different types a considerable range in sugar content is found.

It is of interest, therefore, to follow the chemical transformations occurring in these different corns and to correlate the findings with those of practical canning tests. The analytical data are presented in Table 2 and are illustrated graphically in Figures 3 to 6, inclusive.

In the consideration of these figures and the following discussion of them it must be borne in mind that only a few varieties of the different types of corn have been included in the present experiments. The conclusions drawn from these results, therefore, may be found untenable when a larger number of varieties have been studied.

<table>
<thead>
<tr>
<th>Type or variety</th>
<th>Stage of maturity in days</th>
<th>Total solids</th>
<th>Alcoholic extract</th>
<th>Residue</th>
<th>Fresh-weight basis</th>
<th>Moisture-free basis</th>
<th>Sugars</th>
<th>Total</th>
<th>Reducing</th>
<th>Sucrose</th>
<th>Water-soluble</th>
<th>Total</th>
<th>Poly saccharides</th>
</tr>
</thead>
<tbody>
<tr>
<td>Golden Bantam (sweet)</td>
<td>15</td>
<td>41.27</td>
<td>4.57</td>
<td>6.17</td>
<td>3.56</td>
<td>14.26</td>
<td>22.23</td>
<td>64.34</td>
<td>2.57</td>
<td>3.63</td>
<td>6.05</td>
<td>40.09</td>
<td>20.00</td>
</tr>
<tr>
<td>Waxy maize</td>
<td>15</td>
<td>41.27</td>
<td>4.57</td>
<td>6.17</td>
<td>3.56</td>
<td>14.26</td>
<td>22.23</td>
<td>64.34</td>
<td>2.57</td>
<td>3.63</td>
<td>6.05</td>
<td>40.09</td>
<td>20.00</td>
</tr>
<tr>
<td>Yellow Assini boine (flint)</td>
<td>15</td>
<td>41.27</td>
<td>4.57</td>
<td>6.17</td>
<td>3.56</td>
<td>14.26</td>
<td>22.23</td>
<td>64.34</td>
<td>2.57</td>
<td>3.63</td>
<td>6.05</td>
<td>40.09</td>
<td>20.00</td>
</tr>
<tr>
<td>Rhode Island White (flint)</td>
<td>15</td>
<td>41.27</td>
<td>4.57</td>
<td>6.17</td>
<td>3.56</td>
<td>14.26</td>
<td>22.23</td>
<td>64.34</td>
<td>2.57</td>
<td>3.63</td>
<td>6.05</td>
<td>40.09</td>
<td>20.00</td>
</tr>
</tbody>
</table>

TABLE 2.—Percentage composition of corn of different types and varieties at different stages at maturity
The two varieties of flour corn used in these tests proved to be early, reaching the silking peak about 53 days from the date of planting and maturing very rapidly after pollination had taken place. It was unfortunate that a late variety was not included in this group.

As already pointed out, the flour type of corn is characterized by a soft, starchy endosperm, the cornaceous or flinty portion being very thin and inconspicuous. The floury character of the kernel contents, according to Weatherwax, is due to the relatively small amount of

\[^{10}\text{Weatherwax, P.} \quad \text{THE STORY OF THE MAIZE PLANT.} \quad 247 \, \text{p., illus.} \quad \text{Chicago, Ill.} \quad [1923].\]
protein or colloidal carbohydrate occupying the interspaces between the starch grains. The size and shape of the starch grains may also be in part responsible for the condition.

Examination of the analytical data shows that with respect to moisture content at the different stages of maturity the flour corns were lower than all the other varieties studied, except the flint corns at the 30-day stage, and the waxy maize, which the flour corns paralleled during the first 20 days of development and then exceeded in the later stages. The higher moisture content in the 25 and 30 day corn was due probably to the failure of the kernels to become as compactly filled as in the case of the waxy type.

The sugar content of the flour corns was lower than in the sweet corns, although the maximum attained was above 5 per cent. The decrease in amount was rapid after the 15-day stage and in the 25 and 30 day corn the sugar content was lower than in any of the other varieties studied.

The water-soluble polysaccharides were very small in amount and did not increase significantly in the corn beyond the 15-day stage. The very low content of water-soluble polysaccharides in the later stages is particularly significant and helps to explain the floury character of the endosperm.

The percentage of total polysaccharides present in corn is determined to a large degree by the moisture content. The polysaccharides increase as the moisture content decreases and are less abundant where the moisture content is high. In the present case the proportion of polysaccharides also increased as the kernels became more mature. Considered from the moisture-free basis, the total polysaccharide content of these flour corns during the later stages was greater than in any of the varieties studied except waxy maize. This furnishes in part a chemical basis for their floury character.
Only one variety of waxy maize was available for these studies. Waxy maize is a very distinct type of corn, resembling in general form and appearance some of the flint varieties. The endosperm, however, on breaking has a waxlike appearance, which has given rise to the name applied to this type of corn. The waxy character applies to physical appearance only, the polysaccharide of which it is principally composed being erythro-dextrin, according to Weatherwax. This was the latest of the varieties studied. It required 96 days to reach the peak of silking and remained green for a considerable period.

The analytical data show a low moisture content throughout the entire period of development and maturing of the kernel. The moisture decreased continuously and rapidly up to 30 days from silking, when the amount present was slightly less than 45 per cent. The polysaccharide total was very high, corresponding to the low moisture content, and consisted almost entirely of dextrin, as indicated by the iodine test. Its solubility, however, was entirely different from the ordinary dextrin, as a large proportion of it was insoluble in cold water. The water-soluble portion in the early stages of development was about the same or slightly greater in amount than in the sweet corns. In the waxy maize 25 and 30 days old, however, the proportion was very much less than in the sweet corns. This is very clearly shown in Figure 6.

The sugar content of waxy maize was somewhat lower than in Stowell's Evergreen and Golden Bantam, about equal to that of the flint varieties, and somewhat higher than in the flour corns and the dent variety, Second Early Adams. The total sugar content amounted to about $5\frac{1}{2}$ per cent in the corn at the 15-day stage, but the ratio of reducing sugars to sucrose was high, indicating for the corn a degree of sweetness somewhat lower than the percentage of total sugars would ordinarily signify.

FLINT CORNS

The two flint varieties used in these tests were typical of the New England grown corn of the flinty type, the hard, full, and well-rounded kernels of the mature corn being borne on long slender ears. In field behavior and in general appearance of the ears the two varieties tested were similar, differing only in the color of the grains.

These flint corns were medium late in maturing. It required about 73 days after planting for each to reach the silking peak.

According to Weatherwax, the flinty or horny character of the endosperm in the flint corns is due to the presence in the cells of protein and colloidal carbohydrates which completely fill the interspaces between the starch grains.

The chemical analyses show that the flint corns in this case had a rather high moisture content during the early stages of development. As maturity advanced, however, the moisture content fell off rapidly. the corn 30 days old averaging lower in moisture even than the flour corns, and only about 3.2 per cent higher than waxy maize.

Figures 2, 3, and 4 indicate that during the early stages the flint corns developed somewhat more slowly than the flour corns and waxy maize, and therefore had a higher moisture content.

The flint corns developed a somewhat greater proportion of water-soluble polysaccharides than the flour types, especially in the later stages of development, but they were far below the types of sweet corn in this respect. This is clearly shown in Figure 6. During the later stages of development the total polysaccharide content was higher in flint corns than in the sweet types, and averaged about

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the same as the flour types at the 30-day stage of maturity. In sugar content the flint corns were considerably lower than the sweet corns but higher than the flour corns, especially as maturity approached.

DENT CORNS

In the physical structure of the kernel the dent corns are intermediate between the flint and the flour types, the endosperm, as earlier pointed out, having two distinct portions, an outer horny or flinty portion and a central floury core extending to the tip of the grain. The shrinkage of this portion at the tip of the kernel as it dries out is what gives to it its dented form.

Only one representative of this group, Second Early Adams, was grown in the present case. This is a very early corn, requiring, under the present conditions, but 55 days after planting to reach the peak of silking. In this respect it compares favorably with Golden Bantam. Its earliness, tenderness, and other attractive qualities make it a favorite among truck-crop growers for the fresh-corn market.

In moisture content and in total polysaccharides, also, the Second Early Adams resembled Golden Bantam. In the proportion of water-soluble polysaccharides, however, this variety more closely resembled the flour corns, the amount present being small.

While a maximum total sugar content of a little over 5 per cent developed in the corn 15 days old, nearly one-half of the entire amount consisted of reducing sugars, indicating a corn low in sweetness. The sucrose present, however, did not disappear as rapidly as in the sweet varieties or the flour corns as maturity approached. In this respect Second Early Adams behaved like the flint and the waxy corns.

For the sake of a better understanding of the behavior of dent corns in general during the development and maturing of the kernel, reference is made to the results of similar tests upon two other dent varieties, Boone County White and Reid Yellow Dent, recorded in the earlier paper already mentioned. While the percentages vary somewhat, the results obtained for these varieties show the same general trend as those given here for Second Early Adams. In the charts accompanying this discussion curves illustrating the findings on Boone County White in this earlier work have been included for comparison.

SWEET CORNS

The physical characteristics of the two sweet corns, Golden Bantam and Stowell’s Evergreen, are too well known to require detailed consideration here. The story of their chemical behavior during the development and maturing of the kernel has already been told. Under the conditions of the present season Golden Bantam required 54 days after planting to reach the silking peak, while Stowell’s Evergreen, planted the same day, required 66 days to reach the same stage of development.

A third variety, which for lack of a definite name has been termed here “Guatemalan,” was included in this group because it was known to be one of the very latest of the sweet type. In this case it required 92 days to reach the peak of silking.

The moisture content of these different varieties is of particular interest to the writers. In the earlier study, Golden Bantam, an early

variety, was found to have a relatively low moisture content, and Stowell's Evergreen, a late variety, was found to have a very high moisture content. The conclusion drawn from these earlier studies was that a close correlation exists between the moisture content and rate of maturing of the corn. The present study has confirmed the previous conclusions with regard to Golden Bantam and Stowell's Evergreen. When Guatemalan sweet was analyzed, however, it was found that instead of having a moisture content higher than that of Stowell's Evergreen, which required 66 days to reach the silking peak, its moisture content was actually considerably lower than that found in Golden Bantam, which required 54 days to reach the silking peak. Since, as already mentioned, Guatemalan required 92 days to reach the peak of silking, it is evident that the moisture content is a specific characteristic of the variety and is more or less independent of the rate at which the corn matures.

As a group, the sweet corns, together with the dent corn, had a relatively high moisture content, particularly in the later stages of maturity.

The outstanding features in the chemical composition of the sweet corns were a relatively high sugar content and a high percentage of water-soluble polysaccharides, consisting of dextrin and soluble starch. In the case of the Guatemalan sweet the maximum sugar content was 5.5 per cent, which point was also equaled or approached by several of the nonsweet corns; but the percentage of sucrose in Guatemalan was higher than in any of these.

With but one exception—that of the Guatemalan sweet in its, early stages of development—the sweet corns were lower in total polysaccharides throughout their entire development than the flour, flint, and waxy corns.

Taking into consideration these carbohydrate relationships, it would appear that among the flour, flint, and waxy corns there is a greater tendency for the sugars to be completely converted into starch than in the sweet and dent corns. On the other hand, the metabolic processes by which the sugars are converted into starch are partially arrested in the last-mentioned types, permitting an accumulation of sugar, but resulting ultimately in a lower polysaccharide content. In the flints and in the horny portions of the dent corns the starch grains seem to be embedded in a matrix consisting largely of soluble starch, while in the flour corns and the floury portion of the dent endosperm this matrix seems to be almost entirely absent. In the sweet corns a large amount of dextrin and soluble starch forms the matrix for the relatively few starch grains. This gives to the sweet-corn kernel its translucent endosperm. It is the loss of water by the endosperm in drying that causes the wrinkling of the grain.

CANNING TESTS

In order to observe the effect of the physical and chemical properties of corn of the types herein discussed on the quality of the canned corn, sample lots of ears were harvested from the different varieties, at the 20-day stage of maturity, and sample packs prepared from each. The canning methods employed were the same for all varieties, so that the canned products were strictly comparable. At the end of the season and at irregular intervals thereafter sample cans from the various lots were opened and the products subjected to careful comparative study. The results of these tests are presented below.
SWEET CORNS

The canned products from the Golden Bantam and Stowell's Evergreen were characteristic for these varieties and did not differ from those previously described.\textsuperscript{15,16} They were tender, of good texture and creamy consistency, sweet, and well flavored. They easily graded as first-quality products.

The canned corn from the Guatemalan sweet was somewhat poorer in quality. It was not so tender, the consistency was heavier, and it was less sweet. It was apparent that toughness was responsible to a considerable extent for the poorer product obtained from this variety.

These findings were in accord with the results of the chemical analyses and the earlier tests for toughness. Figure 2 shows that the puncture-test readings for Guatemalan sweet were considerably above those for Golden Bantam and Stowell’s Evergreen. Table 2 and Figures 3 and 4, on the other hand, indicate that Guatemalan was lower in moisture content and in sugar than either of the other varieties. The puncture tests on the raw corn provided an accurate index of the tenderness of the corn in the can, while the moisture content was reflected directly in the consistency of the canned product.

FLOUR CORNS

The canned products from the two varieties of flour corns were similar in all respects. They were hard and tough, dry, and lacking in sweetness, and instead of the desirable flavor characteristic of sweet corn there was a hominylike taste which detracted from the quality. The creamy consistency observed in the products from the sweet varieties was entirely absent from the products of the flour types. These corns, therefore, were found to be wholly unsuited for canning purposes.

The two features most seriously affecting the quality in the flour corns were the extreme toughness of the kernel hulls and the hard, lumpy character of the kernel contents. Figure 2 shows that the pronounced toughness of the pericarp was foretold in the puncture tests, while a comparison of the chemical data on polysaccharides shows the reason for the hard and lumpy character of the product. In the case of the sweet varieties approximately one-half of the total polysaccharides were soluble in cold water. These gave to the canned product a creamy character, whereas in the flour corns only small quantities of water-soluble polysaccharides were present, the bulk of these being composed of starch which merely swelled during the canning process.

Water-soluble polysaccharides play a very important part in determining the quality of canned corn.

WAXY CORN

The canned product from waxy corn was likewise of poor quality. The kernel hulls were very tough, which detracted materially from the attractiveness of the corn. The product was rather dry in consistency. The kernel contents, while somewhat hard, were waxlike or


gummy rather than starchy in character. The corn was fairly sweet, but there was no distinctive flavor. This type of corn was decidedly unsuited for canning.

These findings have their confirmation and explanation in the physical and chemical data already presented. The puncture tests showed this variety to have a very tough pericarp. The low moisture content found accounts for the heavy consistency, while the mixture of nonsoluble and water-soluble dextrins explains the peculiar waxlike texture of the product.

**FLINT CORNS**

The canned material from the flint varieties, although not quite so dry, resembled in physical appearance the product from the flour corns. The hulls present were tough and the kernel contents hard and lumpy. It was lacking somewhat in sweetness, but the flavor was superior to that of flour corn. On the whole, the flint-corn product graded slightly higher than that from the flour corns but was far inferior to the product from the sweet varieties. The most objectionable features were the tough hulls and the hard kernel contents.

**DENT CORN**

The Second Early Adams was much more tender than any of the other field varieties. This tenderness was reflected in the quality of the canned product. In this respect it closely approached the sweet corns. The flavor and sweetness of the product were also very satisfactory. It lacked the smooth texture and creamy consistency characteristic of sweet corn, however, and the rather lumpy character of the kernel contents detracted from the quality of the canned material.

These findings agree well with those resulting from the puncture tests and the chemical analyses. The lack of creaminess finds its explanation in the low percentage of water-soluble polysaccharides in dent corn.

**DISCUSSION**

In the present work various types of corn have been studied and the possibility of their use for canning purposes has been discussed. The object of this investigation, however, was not so much to determine the merits of the different types for canning as to make through them an analysis of the factors which constitute what is termed "quality" in canned corn.

Two groups of factors influence quality in canned corn. One has to do with harvesting methods and cannery practices, and the other with the natural properties of the corn itself. It is the last-named factor with which this investigation is concerned. Of the factors included in this group may be mentioned the toughness of the pericarp, the consistency or creaminess of the kernel contents, the sugar content or sweetness, the moisture content, the compactness of the insoluble material in the endosperm, and the flavor.

The relative importance of any factor depends upon the degree of variation which occurs, the readiness with which it may be corrected by methods of handling, and the way it is affected by other existing factors. Thus, if sugar content is the only significantly variable factor, the variety having the highest sugar content is the most desirable; and if the outstanding variation is in the tenderness of the pericarp, that corn in which it is toughest is the least desirable.
A study of the types here discussed shows that the tenderness of the kernels varies widely, both with the degree of maturity and with the type of corn, as well as with the varieties within the types. The sugar content is quite variable in the different types and in the varieties within the types. It varies much more widely, however, with the degree of maturity. The texture and consistency of the canned product also is subject to considerable variation, the former with the type of corn used and the latter both with the type and the degree of maturity. Flavor is much less variable. Significant variations do occur, but the differences seem less objectionable than variations in tenderness. The significance of these factors will be discussed in greater detail in the following paragraphs.

TENDERNESS

The results of the experimental work reported above indicate clearly that of the inherent properties which affect the quality of canned corn, the degree of tenderness of the pericarp is most important. In measuring this degree of tenderness or toughness by mechanical means some slight error is involved because of the structure of the underlying tissues, which give support to the kernel hull. When the kernels are compactly filled with starch and dextrin, as in the corn at the more mature stages, the readings are correspondingly high. This is not an important consideration, however, for experience has shown that the puncture-test readings furnish a very reliable working index of the probable tenderness of the cut-out corn.

The quantity of the pericarp entering into the canned product has an effect on the apparent toughness or age of the corn. Thus, corn that is a little tough will appear more tender and less mature if it is double cut or slit and scraped than when canned in the so-called "Maryland style," where the kernels are practically whole.

The toughness of the pericarp is not noticeably affected by an increase in the processing period. Tough corn could not be made tender even if the objectionable features of overprocessing could be surmounted.

In general the field varieties are considerably tougher than the sweet varieties at comparable stages of maturity. This in large measure accounts for their being unsuited for canning purposes. The dent varieties used in these and preceding tests were found to be more tender than the other field types. Second Early Adams, belonging to this group, was about as satisfactory from this standpoint as Golden Bantam or either of the other sweet varieties.

The age of the corn, or its degree of maturity, determines very largely the degree of toughness of the kernel hull. The toughness increases steadily and, in many cases, rapidly as maturity approaches. Were it not for the fact that other factors besides toughness have to be taken into consideration in the grading of corn for canning, it could be harvested when young and tender. In very young corn, however, those constituents which give proper body or consistency to the canned product are lacking. Too often, therefore, tenderness is sacrificed to consistency.

It seems evident that the most satisfactory way to meet the requirements for tenderness is to can the corn at as early an age as the consistency of the kernel contents will permit, and to endeavor by selection and breeding to develop tenderer strains, so that more mature corn may be used without sacrifice of quality.
TEXTURE AND CONSISTENCY

Although the body or consistency of the kernel contents usually determines when the corn shall be harvested, the experiences of the present work have forced the conclusion that this factor holds second place in determining quality.

Two elements enter into the determination of consistency—the nature of the polysaccharides present and the moisture content. It will be recalled that about one-half of the total polysaccharides present in sweet corns at canning maturity are water-soluble, being in the form of dextrin or dextrinlike compounds. These are responsible for the creamy texture of the canned product and when combined with the proper amount of moisture give the desired body to the canned material. In order to get the proper consistency it is always necessary to add liquid to the cut-off corn. If too little liquid is added or the corn is too mature the finished product will be too dry or viscous. Regardless of how much or how little liquid is added to it, the canned product of very young corn will not be creamy, because sufficient polysaccharides have not been stored in the kernels.

The water-soluble polysaccharides are practically absent in all field varieties except the waxy corn. On account of the presence of starchy lumps the canned product from these varieties is more or less granular and the creamy texture is entirely lacking. While considerable quantities of water-soluble polysaccharides are present in the waxy maize, the remaining carbohydrate is so compactly stored in the kernel that the texture and consistency are unsatisfactory.

The consistency of canned corn is modified greatly by the method of cutting and by precooking. The fineness with which the corn is cut affects both the appearance of the pack and its consistency, and the product is given a smoother and more creamy texture by the agitation given to the corn in the precooker.

In Maryland-style corn where the kernels are removed from the ear nearly whole, a viscous or cloudy liquor is objectionable and consistency is of no consideration. "Blanching" corn on the cob prior to cutting, as is sometimes practiced by home canners, yields a product that is less creamy. This is accounted for primarily by the fact that the kernel contents are coagulated by the heat and less of the material passes out into the added liquid.

SUGAR CONTENT

Natural sweetness is next in order of importance among the factors affecting quality in canned corn. The sweetness is roughly proportional to the total quantity of sugar present. The quantity and relative proportions of the different groups of sugars in corn are constantly changing as development proceeds. At the time corn is ordinarily canned, sucrose, or cane sugar, is responsible for most of its natural sweetness. The ease with which deficiency in sweetness may be remedied by the addition of sucrose in the brine has raised some question as to whether natural sweetness is of much significance in corn. Sweet corns, as a rule, contain more sugar than the field varieties. In some cases, however, the difference is not great. Occasionally, also, where the sugar content is relatively low, other desirable features, such as tenderness, for instance, make the corn more acceptable than others having a higher sugar content. The present study indicates that natural sweetness is not often the deciding factor in the choice of the best type or the best variety of corn.
Corn containing 5½ per cent of sugar, or approximately the concentration normally present in corn at its highest sugar content point, is considered most desirable for the canned product. When corn is ready for canning it has passed somewhat beyond its highest point of sweetness, therefore it is necessary to add sucrose at the time of canning in order to obtain the most acceptable product. The quantity varies from 4 to 10 per cent in the brine, depending on the condition of the corn. The average brine contains about 6½ per cent of sugar.

It is the opinion of some that added sugar fails to supply the quality of sweetness produced by the natural sugar of the corn. Lack of sugar, however, is nearly always associated with other objectionable properties in the corn, such as toughness, too heavy consistency, and poor flavor, so that it is questionable whether this opinion has much weight.

Since the percentage of sugar in any variety is constantly changing, it might be supposed that the stage of maturity at which the sugar content was highest would be optimum for canning. This is not the case. In the region of Washington, D. C., for instance, corn reaches its highest sugar content about 15 days after the first appearance of silks; but at this stage the corn, particularly of the late varieties, is much too immature to give desirable body and flavor.

High sugar content is desirable in corn for canning, and contributes much to the quality of the canned product. Other factors, however, appear to be of considerably more importance.

**FLAVOR**

Sweetness in corn constitutes much of what the average person considers flavor. Experiments show that corn in prime canning condition which is canned without sugar lacks the flavor of corn canned with sugar. High sugar content, however, does not always mean high flavor or quality. In the present tests corn 15 days old from silk, though higher in sugar content than others more mature, was considered by nearly all judges as lacking in flavor. Just what chemical constituents are responsible for the pleasing characteristic flavor of prime sweet corn is not known.

Very small differences in flavor occur in varieties of the sweet type at comparable stages of maturity, such differences being more particularly marked between the white and the yellow varieties. The variations in flavors among the different types of corn are somewhat greater. Only in rare instances, however, are even these type differences considered of much importance.

As corn approaches maturity the pleasing flavor gradually disappears and is replaced by one considerably less attractive.

**COMPACTNESS OF THE ENDOSPERM**

As already suggested, a part of what is usually considered toughness is really due to the compactness of the endosperm. In the flint corns, and in the waxy type especially, the endosperm is very hard and compactly filled with carbohydrate. This becomes especially marked as the corn approaches maturity. The endosperm of the sweet varieties is much less compact than that of any other type. There is considerable variation among the sweet corns in this respect, as was shown by the Guatemalan sweet and Stowell's Ever-
green in the present tests. The kernels of the Guatemalan sweet were considerably more compactly filled than Stowell's Evergreen, as shown not only by physical appearance but also by their lower moisture content.

As affecting the quality of the product from the varieties usually canned this factor probably is not of much significance.

**CELLULAR STRUCTURE**

No histological studies were made of the different types of corn used in these tests. The readiness with which the contents of the kernels of some of the sweet varieties escaped into the liquid during the canning process, however, suggests that there may be some marked difference in the cellular structure. Size of the cells or thickness of the cell walls may vary considerably in the different types and varieties and may have some influence on the quality of the canned material obtained from the different corns.

**SUMMARY**

Several types of maize have been studied with respect to the degree of toughness of the pericarp, the chemical composition of the kernels, and the canning quality of the different types.

There is great variation in the different types and in all types at different stages of maturity in the toughness of the pericarp. The degree of toughness is much greater in the flour, flint, and waxy types than in the dent and sweet corns. This toughness is particularly marked with the approach of complete maturity.

The most characteristic difference in chemical composition is found in the content of water-soluble polysaccharides. The sweet corns have a very high proportion of this constituent. It is relatively high also in the waxy maize but rather low in the flint, dent, and flour types.

There is a very significant difference in the various types as well as in varieties of the same type in the moisture content of the developing kernels. This difference generally becomes more marked as maturity approaches.

In general, the sugar content is higher in the sweet varieties than in the other types, but the differences are not so marked as might be expected, in view of the preference generally shown to sweet corn for table purposes.

In tests upon the relative quality of the different types for canning purposes the sweet corns were found superior to all other types, followed in order by the dent, waxy, flint, and flour types.

From a study of the data here presented it is possible to list the following as factors which are preeminent in determining the quality of the canned product:

1. The degree of tenderness or toughness of the pericarp.
2. The nature of the polysaccharides present, and the ratio of water-soluble to total polysaccharides.
3. The sugar content.
4. The compactness with which the polysaccharides are laid down in the endosperm, and possibly the cellular structure of the endosperm itself.