AN EVALUATION OF SEVERAL METHODS OF DETERMINING THE OPTIMUM MATURITY OF SWEET CORN FOR PROCESSING

by

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ABSTRACT

A study was undertaken to assess various methods which could be used to determine the maturity of sweet corn and the proper harvest date for processing.

Two commercial varieties were grown and a series of harvests was made, ranging from immature to overmature. Ten characteristics of the fresh corn were measured. Samples of each harvest were canned and frozen and the same characteristics of these samples were measured. The canned and frozen samples were rated by a sensory panel.

Moisture content was assumed to be the standard measurement of maturity and the other methods were compared to it. Simple correlation coefficients between the various characteristics were determined. An analysis of variance was made on the sensory panel scores.

The refractive index was the most reliable and accurage method of determining maturity and it could be determined more quickly and simply than any of the other measurements. Alcohol-insoluble solids content and trimetric rating were accurate and reliable methods but they were too slow to be of practical use. Pericarp content and shear press rating were not sufficiently accurate. The sensory panel results were not always consistent with the objective measurements.

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INTRODUCTION

Sixteen hundred acres of sweet corn are grown in Manitoba for canning. Most of this is for cream style corn since, until recently, there were no varieties which were of high enough quality for whole kernel canning or freezing and which, at the same time, matured early enough in Manitoba. One of the major problems of the whole kernel processing industry is that of deciding when to harvest the corn in order to get the desired quality in the canned or frozen product. This is much more critical in canning whole kernel corn than in cream style because deficiencies in quality cannot be easily overcome by additives. Since well adapted, high quality varieties are now available in Manitoba, it is important that methods be developed for determining the optimum stage of maturity for harvest.

A test of raw corn maturity and quality must be simple and rapid, since under favorable weather conditions a field of corn can rapidly reach optimum quality and begin to deteriorate. Processors employ various methods to determine the harvest time of sweet corn. The success of these tests in determining the quality of the corn can be influenced by such factors as weather and seasonal conditions, varietal differences, and the accuracy of the method itself. The eating quality of corn is determined by the toughness and amount of pericarp, starch and sugar content, color, succulence, and flavor; any test of quality should take these factors into account.

Some processors still use the thumbnail test of maturity; although it is a subjective test an experienced person is able to determine the maturity fairly accurately by observing the color, firmness, size of ear, and puncture of the kernels. However, this test does not give any indication of flavor or sweetness, and the results may vary between individuals.

The moisture content is used as a standard index of sweet corn maturity. There are several methods of measuring moisture content, but many of them are either too slow or too inaccurate for practical use. The value of moisture content as a maturity index lies in its close association with such factors as starch content, sugar content, sugar: starch ratio, succulence, and pericarp content. The refractive index of the juice is a measure of the total soluble solids. The procedure is a rapid one, and the results are closely correlated with the sugar: starch ratio, moisture content, sugar content, and starch content.

Determinations of pericarp content and alcohol-insoluble solids content are indicators of certain of the quality factors, namely tenderness and starchiness. Both of these tests take considerable time to complete and must be done with care if they are to be accurate.

A trimetric rating, consisting of a combination of moisture content, pericarp content, and kernel diameter is considered to be a reliable index of maturity and quality, although its usefulness is limited by the time required to carry out the determinations.

There are several instruments which measure succulence, such as the succulometer and the compression cell of the shear press. The texturemeter, tenderometer, and the shear cell of the shear press measure the texture or toughness of the kernels. The shear and compression readings of the shear press can be combined into a single value by means of a regression equation and several workers have reported that this rating is an accurate indication of sweet corn maturity.

There is as yet no instrumental method of measuring the flavor aspect of sweet corn quality. Sensory panels can be used to evaluate eating quality if they are selected with care and conducted under the proper conditions. Attempts are being made to relate the results of sensory panels to objective, instrumental tests which could then be used to evaluate the maturity of the corn. Ultimately these objective methods must be correlated with consumer preferences.

REVIEW OF LITERATURE

A complex series of chemical and physical changes occurs in the corn kernel during maturity, and many studies have been made of these changes and methods of measuring them. Culpepper and Magoon (9) found that during growth and maturity, dry matter increased, total sugar increased up to 15 days after silking and then decreased rapidly, reducing sugar decreased, non-reducing sugar (sucrose) increased up to 15 days after silking and then decreased, water-soluble polysaccharides increased rapidly, and total polysaccharides calculated as starch increased rapidly. Total solids increased more or less regularly as maturity advanced (9,10, 34) and were closely associated with total polysaccharides as starch, total sugars, and the sugar; starch ratio. The edible stage is between 25 and 35% total solids and in this range the relationships between total solids and the carbohydrate constituents are essentially linear and are closely correlated (21).

Percent reducing sugars and total sugars showed a downward trend with maturity. Flavor, skin texture, endosperm texture, and color deteriorated as the corn matured. This lowering of quality was most rapid after the moisture content fell below 70% (19).

The pericarp increased in toughness as maturity advanced (3,20). The toughness of pericarp is difficult to measure since factors such as endosperm firmness, variation between kernels on the same ear, varietal differences, and seasonal differences influence the measurements (20). Puncture index was very significantly correlated with moisture content (24). Kramer (27) stated that texture must be measured and defined in physical-numerical terms. The forces which may be used to measure texture are compression, tensile strength, cutting force, and shearing force. In evaluating maturity, texture is involved, but its measurement is made more difficult by other quality factors such as flavor, size and color.

The following factors were considered to determine the quality of canned corn: 1) degree of tenderness or toughness of the pericarp, 2) the nature of the polysaccharides and the ratio of water-soluble to total polysaccharides, 3) sugar content, and 4) the compactness of the polysaccharides in the endosperm (10).

Several methods of estimating the stage of plant growth on the basis of seasonal temperatures are described by Huelsen (20). The degree-hour summation above the base-line of 50°F is the only one in practical use. Although this method may give a rough approximation of maturity, the variation from season to season is too great to allow it to be used with confidence (33). The number of heat units required for the maturity of a crop is influenced by environmental factors such as rainfall, soil type and fertility, and topography (4,38).

The tests of raw product quality which have been developed are based on visual inspection, moisture content, toughness and amount of pericarp, total soluble polysaccharides, succulence, and specific gravity.

Some packers use the thumbnail test in which the maturity is determined by the amount of dough in relation to the milk. A trained fieldman can determine maturity fairly reliably (2).

Dry matter increases as maturity advances and is a good indication of quality and maturity. To measure the dry matter accurately it is necessary to dry the sample at 80°C in a vacuum oven until the weight is constant; the disadvantage of this method is the time required to complete the test (20). The Brown Duvel moisture test (37) is more rapid, but less accurate, showing a variation of 1.5 - 2.0% from vacuum oven moisture (7,20). Nine samples would be required to yield moisture values approximately equivalent to one vacuum oven sample (13). The Steinlite moisture tester is accurate and rapid, and is considered to be an adequate test of maturity (13, 19, 20). The Brabender test is an accurate method of measuring moisture content, but it is too slow (6, 20, 37).

Several tests have been developed to measure toughness and amount of pericarp. There is a fairly good correlation between the amount of pericarp and the maturity of corn (30). The amount of pericarp is determined by grinding a sample, washing it through a screen, and drying it in an oven. Several puncturing devices have been used in attempts to measure pericarp toughness (3,9,11,21,44). Although the accuracy of these instruments is influenced by extraneous factors, some of the puncture tests demonstrated significant differences in tenderness. Percent moisture was negatively and very significantly correlated with puncture index (3,11,44).

The use of the refractometer to measure total soluble solids is described by Scott, Belkengren, and Ritchell (41). The Gaertner refractometer is more suitable for this work than the Abbe-type. Since the liquid from the sample is not a clear solution, the image seen is not a sharp line; in the Gaertner instrument the light is divided and recombined, giving two light fields separated by a dark field. The correct setting is that at which the dark line just disappears. Calibration charts should be prepared for each variety by determining both refractive index and moisture (or some other index of maturity). The refractive index varies less than moisture tests with changes in the weather, and there is a close correlation between refractive index and sugar: starch ratio (41).

Sacklin, Kyle, and Wolford (39) found that a single calibration chart could have been used to predict the moisture of all varieties tested. Other workers have also reported the refractive index to be an accurate and rapid method of determining maturity (7,19).

Since starch and insoluble polysaccharides are closely associated with moisture content, the determination of these substances is an accurate method of determining maturity (20). Jenkins (22) developed a method using the alcohol-insoluble residue, that is the starches, hemicelluloses, fibre, and proteins, as a measure of quality; the method was later simplified (24). Several other methods of determining starch, insoluble polysaccharides, reducing sugars, and non-reducing sugars have been proposed but are not in general use (20). A method of measuring maturity based on the light-scattering effect of the components of the kernel when blended and suspended in water has been suggested (23). It is stated that the method is highly sensitive, reproducible, and rapid.

The succulometer is a hydraulic press which expresses the juice from the corn kernels. The succulometer readings correlate well with the alcohol-insolubles test for canned corn and with moisture content of the raw corn (30,31). The texturemeter operates on the principle of forcing a multiple spindle through the corn kernels in a perforated cup (20). A shear press has been devised with a shear cell consisting of a set of blades which shear through the kernels in a slotted box, and a compression cell which expresses the juice from a sample (5). A bimetric procedure was developed consisting of tests with the shear and compression cells of the shear press; the method was found to be rapid and accurate in determining the tenderness-maturity factor of quality of the raw corn and for canned corn (29). It was equal in accuracy to alcohol-insoluble solids measurement and somewhat less accurate but more rapid than the trimetric test (42). In use on peas, the shear press was equal in precision and accuracy to the tenderometer and superior to the texturemeter (28). Several modifications and attachments of the shear press were described by Hartman, Isenberg, and Ang (17). They tested two of these new attachments and the universal cell, and found that none of them gave consistent correlations with subjective estimates of texture(1).

Specific gravity values obtained from fresh and processed whole kernel corn showed good relationship with fresh product moisture content and with fresh and processed product alcohol-insoluble solids (8). Total solids, moisture content, alcohol-insoluble solids, and total reserve polysaccharides could be predicted by the use of specific gravity techniques. The specific gravity method is the simplest method of estimating maturity (14,35).

Kramer described a trimetric test for sweet corn quality; this test consists of moisture, pericarp, and kernel size determinations and was found to predict processed corn quality accurately, regardless of variations caused by varietal differences or climatic conditions(26).

Although many methods are available for the objective measurement of appearance and kinesthetic factors of quality, evaluation of flavor factors must still be done largely by sensory panels (25). Hening (18) outlines the methods used in flavor evaluation and consumer acceptance tests, and the selection of taste panel members. Kramer and Twigg (32) describe the various types of sensory panels, their proper use, and the statistical analysis and interpretation of the results. Good correlations were obtained between the results of the subjective panel evaluation of the tenderness-maturity factor and the results of the trimetric test (43). Sather and Calvin (40) found that flavour preference scores were related to maturity factors as measured by trained-panel scores for tenderness and maturity, shear resistance, percent moisture, soluble solids, and USDA maturity scores. Flavor intensity and maturity were the only factors affecting preference. Shear resistance, percent moisture, and percent soluble solids were the only physicochemical factors significantly correlated with flavor preference.

There is good correlation between the results of the trimetric test and those of the subjective panel evaluation of the tenderness-maturity factor. The trimetric test may be used with considerable reliability to evaluate the tenderness maturity of canned or frozen whole kernel corn, but the extent of its practical application may be limited by the time required to complete the test (42). The alcohol-insoluble solids content is the most reliable method of determining the maturity of fresh, frozen, and canned corn. Percent soluble solids determined by the refractometer is the most reliable quick method (16). Steinlite moisture meter, succulometer, vacuum oven moisture, and percent soluble solids by refractometer are adequate tests of maturity; the refractive index requires the least amount of time (19). Vacuum oven moisture, crude starch, and alcohol-insoluble solids are not adaptable to quality control for processing because they are too slow. Refractive index was the most rapid, accurate, and useful method of determining maturity (7,15).

MATERIALS AND METHODS

Several methods were used to measure the changes which take place in the quality of sweet corn as maturity advances. These methods were assessed to ascertain their suitability for determining the time of harvest.

Three commercial varieties of sweet corn representing a range of maturities were grown. The varieties and their relative maturities are as follows:

	Variety	Seed Source	Maturity
1.	Carmelcross	Northrup-King	early
2.	NK51036	Northrup-King	mid-season
3.	58-1804C	Rogers Bros.	late

Two 30-foot rows of each variety were planted in each plot, and varieties were randomized within the plots. Nine plots, each corresponding to a different harvest date, were randomized within each of four replicates. The seed was planted at the rate of 60 seeds per row on June 8; hand seeders were used because the soil was too wet to permit the use of a power seeder. The plants were thinned to about 11 inches apart on July 7. Ammonium phosphate fertilizer (11-48-0) was banded about six inches to the side of the row and two inches deep at the rate of 100 pounds per acre on July 8. Urea (45-0-0) was side-dressed on July 23 at the rate of 200 pounds per acre. Two irrigations were made on July 27 and August 11.

When the plants began to silk, the number of silked plants was counted each day. The date of silking for a variety was considered to be the date on which 80% or more of the plants had silked. When the 80% silking mark was reached, the ears on the plants which had not yet silked were removed to prevent the harvest of any extremely young ears.

Beginning September 7, a series of harvests of Carmelcross and NK51036 was made, ranging from immature to overmature. The variety 58-1804C was abandoned because it was extremely late. Eight harvests of Carmelcross and seven of NK51036 were made. Heavy frost occurred on September 25 and 26, preventing further harvesting.

All the ears were picked from each plot and weighed. The ears from the four replicates were bulked. A sample of approximately 90 ears was taken and the kernels removed. Samples were canned and frozen according to directions supplied by the Ontario Department of Agriculture and the United States Department of Agriculture. The following measurements were made on the fresh kernels:

1) Moisture content was determined using both the vacuum oven and the electric oven. A sample of kernels was ground in a Waring Blender for three minutes. Ten grams of the ground material were placed in previously weighed aluminum dishes. Two dishes were dried in the electric oven for two hours at 100°C and two were dried for 45 minutes in the electric oven and then moved to the vacuum oven and dried for three hours at 80°C. The weight of the dried sample minus the weight of the dish, times ten equals percent dry matter.

2) Percent pericarp was determined using the method described by Gould, et al (15). Duplicate 25 gram samples were ground with 200 ml. of water in a Waring Blender for three minutes. The slurry was washed onto previously weighed wire mesh screens and dried in an electric oven at 100°C for two hours. The weight of the dried sample minus the weight of the screen, times four equals the percent pericarp.

3) Percent alcohol-insoluble solids was determined using the method described by Gould, et al (15). Duplicate ten gram samples were ground with 150 ml. of 80% ethyl alcohol in a Waring Blender for three minutes.

The samples were washed into 600 ml. beakers with 150 ml. of 80% ethyl alcohol and simmered for 30 minutes. They were then filtered onto previously weighed filter papers, dried at 100°C for two hours, and weighed. The difference in weight times ten equals the percent alcohol-insoluble solids.

4) The shear press rating was determined using the method outlined by Kramer and Cooler (29) and modified slightly. A 100 gram sample was placed in the compression cell and the cell was placed in position in the shear press. The speed of stroke was set at one minute and the sample was compressed until no more juice was being collected. The volume of juice collected was reported as ml. of juice expressed from the 100 gram sample.

For the shear test, 100 grams of kernels were placed in the shear cell and placed in position in the shear press. The speed of stroke was set at one minute. The force required was recorded on the recorder chart.

The predicted grade score for the tenderness-maturity factor was calculated according to the following regression equation:

$M = 31.5 + 0.461C - 0.00657\ S$, where M is the predicted grade score, C is the ml. of juice expressed, and S is the shear value in pounds force.

5) Kernel diameter was measured by lining up 20 kernels side by side and measuring them at their widest point.

6) Kernel volume was measured by placing 100 kernels in a measured volume of water and noting the increase in volume.

7) The trimetric rating was calculated using the following regression

equation:

U.S. score for maturity = 6.44 + 0.530 S - 5.396 P - 1.261 D, where S is percent moisture, P is percent pericarp, and D is the length in inches of 20 kernels placed side by side (26).

8) The refractive index of the corn juice was measured using a Gaertner refractometer. A small amount of the sample prepared for moisture determination was placed on a cotton wool pad and the juice was squeezed through into the space between the prisms.

The following measurements were made on the canned and frozen corn:

1) Percent pericarp was determined in the same manner as for fresh corn.
2) Percent alcohol-insoluble solids was determined as for fresh corn.
3) The shear press rating was determined as for fresh corn after the samples had been drained for three minutes. The grade score was calculated from the following regression equation:

   M = 36.28 + 0.529 C - 0.0266 S, where M is the maturity score, C is the ml. of juice expressed, and S is the shear value in pounds force.
4) The kernel diameter and kernel volume were measured as for fresh corn.
5) The trimetric rating was obtained using the same regression equation used for fresh corn.

The canned and frozen samples were evaluated by a five-member