The Determination of Raw Pea Grade by Tenderometer . . . A Review

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THE DETERMINATION OF RAW PEA GRADE BY TENDEROMETER - A REVIEW

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Introduction

Over the past thirty years, the Tenderometer has come into general use by processors of peas in the United States as a mechanical device for measuring the maturity grade of raw peas. Maturity in peas refers to the stage of development of the seed at the time of harvest and is largely responsible for textural variations in the processed product, ranging from succulence to starchiness or tenderness to toughness. The maturity-tenderness quality in peas exerts a dominant effect on the consumer acceptance of the product, as attested by the fact that in the U. S. grade standards for both canned and frozen peas (21, 22), 40 to 50% of the total score is assigned to this factor alone. A reliable determination of the maturity of raw peas therefore has considerable importance both to the processor as a basis for control of processing and harvest operations and to the grower as a basis for establishing value of the crop and payment of the processor.

The research department of the American Can Company developed the Tenderometer as an instrument which could be used by the pea processor to measure the tenderness quality of shelled peas by an objective means which would be free from the inaccuracies of human judgment of quality. Martin (14) announced the development of the Tenderometer in 1937 and presented certain reliability data on the machine. Since that time, other investigators and industry groups have studied various questions raised by processors and growers alike concerning Tenderometer operation and reliability under conditions of use. This report is intended to review the existing literature which pertains to use and reliability of the Tenderometer in determining the maturity grade of raw peas and to indicate areas where additional investigation is needed.

Principle and Operation of the Tenderometer

Martin (13) states that the Tenderometer was designed to measure the tenderness-toughness aspect of maturity in raw peas, which is defined as the property of the peas which resists shearing or grinding in the human mastication process. Development of the mechanical system to measure this textural property of peas was based on the following principles:

1. Skin and cotyledons both contribute to toughness in peas; hence the method should measure the combined effects of the two elements.
2. Toughness in peas is measurable in terms of force necessary to compress and shear a confined sample of constant size.
3. Complete automation of the mechanics will avoid human error.

The Tenderometer instrument, shown in Figure 1, stands about five feet high, weighs approximately 700 pounds with counterweight installed, is power driven, and must be leveled on a solid floor before being operated. The operating design of the Tenderometer is described by Martin (14), and by Martin, Lueck, and Sallee (15). The essential parts of the instrument consist of two opposing grids, constructed as a series of rectangular-edged intermeshing metal plates, between which the product is sheared. Figure 2 shows the two grids in the fully disengaged position, forming a chamber which holds about 6 ounces of raw peas. One grid is powered by a motor and is put in motion automatically when the chamber cover is fully closed. When actuated, the powered grid is rotated at a constant rate in a clockwise direction toward the second grid. The second grid is moveable but is held stationary by a weighted pendulum shaft which extends downward in a vertical position. As the powered grid approaches the resistance grid, the pressure exerted on the peas causes the weight pendulum to be displaced from the vertical position. The distance of displacement of the pendulum arm from the vertical position is a measure of the force involved. The displacement continues to increase until the force is sufficient to shear

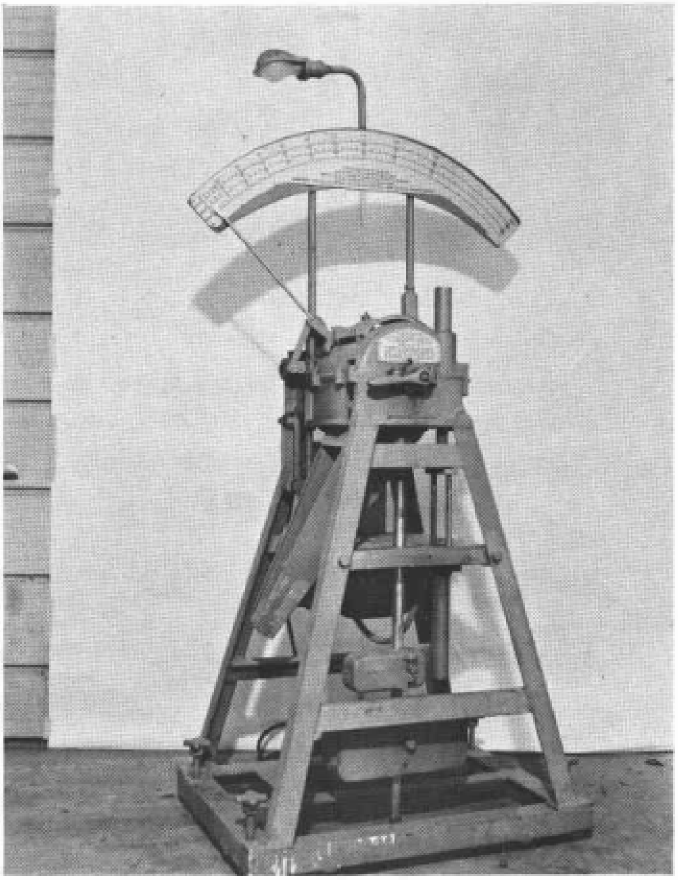

Figure 1. The Tenderometer

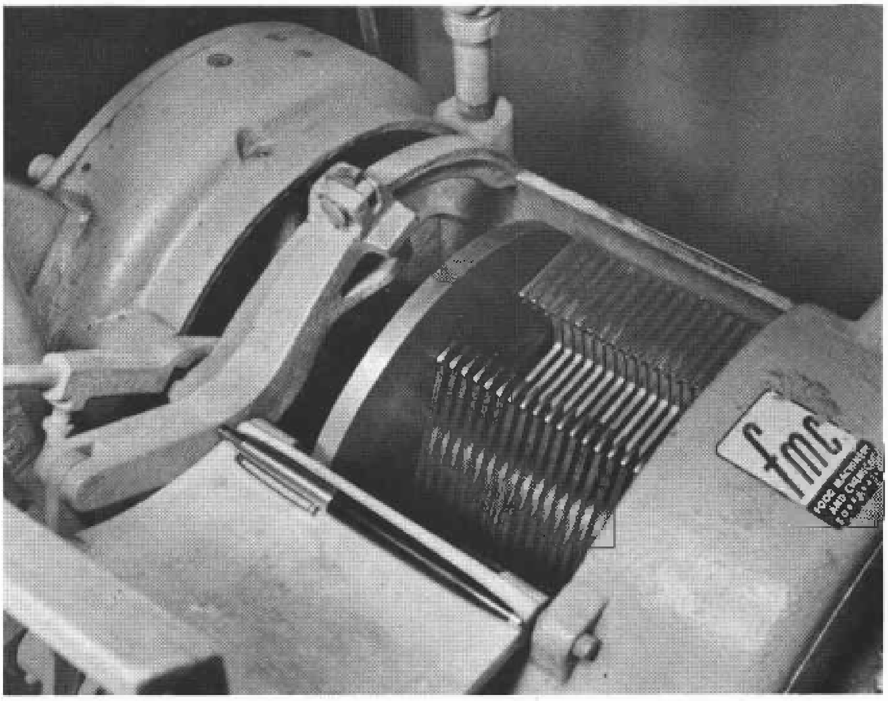

Figure 2. Shearing grid unit of the Tenderometer

the peas. The pendulum stabilizes until all of the peas are sheared through the grids, then returns to the original vertical position.

The Tenderometer reading is shown by a pointer which is activated by the movement of the pendulum to advance along a scale reading in terms of pounds per square inch of grid surface. The pointer comes to rest when the maximum shearing force in the determination is attained. The powered grid continues rotation through a half revolution in order to clear itself of product, then is automatically disengaged from the drive. When disengaged, the powered grid can be returned manually to the zero position ready for the next determination. The operator simply records the pointer reading on the scale and returns the pointer to zero position manually.

Manufacturing rights for the Tenderometer were acquired by the Canning Machinery Division of Food Machinery and Chemical Corporation. Minor changes in design have produced a more rugged instrument, but the basic design has remained the same over the years. An operating and servicing instruction manual (4) supplied by this company provides a list of set-up and maintenance checks which should be made before and during use of the Tenderometer to ensure satisfactory mechanical operation of the instrument. The FMC service manual also describes a mechanical procedure for standardizing the individual Tenderometer and a method of determining the correct position of the force scale pointer in order to assure operating accuracy in the machine. Because the Tenderometer is an analytical instrument which can be easily damaged mechanically or rendered inaccurate, the FMC manual recommends that the Tenderometer be entrusted only to a competent and trained operator, and that samples be carefully cleaned, preferably by washing in water, to reduce wear and prolong the life of the Tenderometer.

Reliability of the Tenderometer Test

Makower (13) points out that "maturity" in peas is essentially a subjective quality which can be measured directly only by a panel of human judges. The validity of the Tenderometer method, or any other objective method, for determining maturity in raw peas depends primarily upon the accuracy with which it can indicate or predict the human judgment of maturity in the processed product. The objective method must then be assessed for validity by testing the correlation or agreement between its readings and those generated either by the human test panel or by a second objective method such as the Alcohol Insoluble Solids (AIS) method of Kertesz (6) which has proved to be valid in the evaluation of maturity in peas.

How valid, then, is the Tenderometer test for maturity of raw peas? Martin, Lueck, and Sallee (15) conducted Tenderometer tests at a number of pea canning plants in the country during 1938. They compared Tenderometer readings on the raw peas with both AIS and commercial subjective grades on the canned product. The correlations obtained between Tenderometer and AIS for four varieties of peas, size-graded and pod run, were remarkably high (Alaska: 0.96, 0.99; Admiral: 0.89; Perfection: 0.95, 0.99; Surprise: 0.99). Correlations between Tenderometer and the commercial grade scores were significant, but the authors noted some wide deviations between plant results which they attributed to variations in canning procedure and inspector error in grading. Walls and Kemp (23) studied the relationship between Tenderometer values of raw peas and AIS percentages on canned peas in over 350 samples of size-graded Alaska peas from one location. Again, a high positive correlation (r=0.96) was obtained, but the plot of values showed a significantly curvilinear relationship between Tenderometer and AIS values. Kramer and Aamlid (9), working with 220 samples of peas covering a wide range of maturity, again reported a very good correlation (Alaska: 0.98; sweet varieties: 0.97) between Tenderometer readings of raw peas and AIS values on canned samples. A significant relationship was found between Tenderometer (raw) and sensory panel scores (canned) for all varieties, but the authors noted that the same Tenderometer reading may correspond to a different average panel score in different varieties of peas. Campbell and Diehl (2) investigated the relationship between the Tenderometer test on raw peas and sensory test panel scores for maturity in the frozen product. Significant negative correlations were obtained for six varieties of commonly frozen peas, as follows: Improved Gradus, -0.75; Roger's 95, -0.94; Stratagem, -0.89; Tall Alderman, -0.83; Thomas Laxton, -0.88; and World's Record, -0.75.

The literature cited gives considerable evidence to support the general recognition by the processing industry that the Tenderometer constitutes a valid method for evaluating the relative maturity of raw peas. However, an assessment of the reliability of the method also involves the question of precision, that is, the amount of variation found in repetitive tests with the same instrument, or in comparative tests between several instruments of the same kind.

Kramer and Aamlid (8) tested the precision of a single Tenderometer and found it to be good, based on sets of 20 replicates from a series of samples ranging widely in Tenderometer value. The coefficient of variation obtained for the Tenderometer readings was 2.26, compared with 2.33 for Shear-press and 5.31 for Texturemeter. Few other sources of data on precision within or between Tenderometers have been found. Tressler (10) notes that a 4 to 11 point spread was normal in a set of 10 or more Tenderometer readings obtained on one lot of raw peas with a single instrument. An extensive series of tests with graded fresh peas yielded a standard deviation value of 2.5 points for readings on one Tenderometer. Graham and Evans (11) found that a range of 10 units could be expected in a series of 10 readings on a single Tenderometer using size-graded peas of Tenderometer range 120 to 130 which were cooled in ice water. Makower (13) pointed out that certain environmental factors and conditions of use of the instrument can increase the variability in Tenderometer readings. The variation among instruments was particularly noted as a problem which is linked to the lack of an adequate standard for calibrating the Tenderometer.

Standardization of the Tenderometer

Reliability in a testing instrument is improved by: (a) standardization of the equipment set-up and operation; and (b) calibration of the instrument using some unchanging standard of measurement. The FMC Operation and Service Manual for the Tenderometer (4) contains a detailed procedure for the mechanical standardization of the instrument before and during use. This procedure considers assembly, leveling, lubrication, adjustment of the scale pointer setting, balancing the counterweight pendulum, and operation. The manual states that a faulty pointer setting is the most frequent cause for incorrect Tenderometer readings, and the setting should be checked each day. Graham and Evans (5) of Unilever, Ltd., observed that the angle bar which actuates the pointer can be rather easily jarred out of adjustment or damaged during operation, so this part should be checked daily and replaced if found damaged. The mechanical standardization procedure for the Tenderometer involves raising the counterweight pendulum to an exactly horizontal position, setting the pointer mechanism to read 200 on the scale with this pendulum position, then balancing the weighted pendulum against a weight of 101 pounds, 2 ounces hung from the end of a test bar which is hooked into the grid unit and extends horizontally out to the right of the instrument.

The mechanical standardization procedure, which FMC recommends for every Tenderometer at the beginning of each season, enables the individual Tenderometer to give consistent readings over a period of use. However, the development of a calibration method which can ensure that different Tenderometers are maintained in agreement with each other has posed a more difficult problem for the manufacturer and the users. Since the inception of the Tenderometer, a search has been under way for a standard, which must be a stable material showing constant resistance to a given shearing force. According to Tressler (18) and Graham and Evans (5), artificial reference materials such as cigarettes, paper, foil, gels, and plastics were tried by various workers. These materials were unsuitable because they failed to simulate the behavior of peas when crushed between the grids of the Tenderometer. In 1949, Tressler (18) announced that graded raw peas preserved in alcohol could serve as a dependable test medium for calibrating Tenderometers at different locations from studies made by National Canners Association and Birdseye-Snider Division of General Foods Corporation. Although Food Machinery Corporation issued the preserved test peas of given Tenderometer reading to all Tenderometer users for one season, the method was discontinued in 1951 because its reliability in the field was suspect. Peas-in-alcohol fell short of an ideal test material because their toughness increased with time of storage in containers and they toughened very rapidly when exposed to air.

Little progress has been made since 1951 in selecting a foolproof test material as a calibration standard; thus other methods of standardization have been advocated. Kramer (7) and Twigg (19) suggested a method for standardizing the Tenderometer by direct comparison with AIS results for the same peas, either raw or after canning. A table relating Tenderometer value to alcohol insoluble solids of raw and canned peas for Alaska and Thomas Laxton varieties was given. The method recommends that the Tenderometer should be adjusted if the actual Tenderometer value (an average of 12 readings) varies by more than five units from the table value indicated by the AIS determination. Later, Twigg (20) prescribed a second method of Tenderometer standardization, using the Shear-press. Twigg points out that the Shear-press is easily calibrated by use of a standardized proving ring. The calibration of the Tenderometer is then based on the Shear-press average pounds force value for three readings and a factor of 5.7 converting pounds force to pounds per square inch. A five-unit deviation between actual and calculated Tenderometer readings is allowed without adjustment of the Tenderometer. It would appear that both the AIS method and Shear-press method of Tenderometer standardization have considerable merit, but application of these methods would be possible only by those companies having laboratory facilities or the Shear-press available.

The Food Machinery and Chemical Corporation, in its manual, recommends only a system of cross-checking different Tenderometers in one locality by making simultaneous determinations on all machines using subsamples of a single graded lot of fresh peas. This is admittedly only a screening procedure to locate and service instruments deviating widely from the average reading of the group. Left to their own resources, users have devised various procedures to maintain agreement between their Tenderometers. One processor reports a system in which he maintains his newest Tenderometer as a master instrument and checks all in-use instruments against it on a weekly basis. Subsamples from a uniformly mature lot of sieve 3 or 4 peas are delivered dry to each Tenderometer site and run simultaneously at a predetermined time in order to ensure similar sample-holding conditions for all Tenderometers. The average readings for three cuts are relayed by telephone to headquarters, and instructions are given immediately if adjustment of a given Tenderometer is necessary. Graham and Evans (5) outline a similar program for cross-checking Tenderometers at Unilever, Ltd. in England. However, these authors transported the raw shelled and graded peas to the Tenderometer sites in Thermos jugs containing ice-cold soft water. Simultaneous tests were run at the field sites and on the master Tenderometer, with telephone communication of results. The test run consisted of 10 readings or more. A later study employed quick-frozen peas thawed for five hours at

37° C as the test sample. Toughness decreased during the first hours of thawing, reaching a stable minimum in five hours. Thawed samples could therefore be delivered to the Tenderometer sites and test runs made without the need for precise timing. Six readings per test were taken and where the average did not agree within ±2.5 units of the master reading, pendulum weights were adjusted on the Tenderometer and the test was repeated. The frozen test samples were prepared by size-grading selected raw peas in the 130 to 140 Tenderometer range, then blanching, brine grading, and freezing the predominant sieve size. The Tenderometer value of the floaters after freezing and thawing was 80 to 100, and of the sinkers 95 to 110. Under frozen storage at -5° F, Dark Skinned Perfection peas were found to toughen slightly during the first nine months; then texture remained constant. The procedure using frozen peas is rather lengthy, but it does provide standardized samples ready for use whenever needed.

Factors Affecting Accuracy of Tenderometer Readings

Most processors of peas recognize the need to standardize each Tenderometer and will start the pea season with their Tenderometers checked out for operation by the mechanical standardization procedure prescribed by Food Machinery Corporation (4) and endorsed by processor associations such as the Northwest Canners and Freezers Association (16). Furthermore, most processors with more than one Tenderometer in service during a season will cross-check their instruments for agreement by running a common control sample of peas through each and adjusting each to read within some selected tolerance of a master Tenderometer reading, or of a reading established by some calibration method. Starting with a standardized Tenderometer, an operator may encounter many conditions which vary during a period of testing. Could these variables affect the accuracy of the tenderness readings shown by the instrument? A number of conditions relative to operation of the Tenderometer have been investigated and are discussed here.

Size and condition of sample. The FMC Tenderometer Manual (4) prescribes a sample of peas that is representative of the lot and of sufficient size to permit replicated tests. The manual stresses a thorough cleaning of the sample by inspection for removal of non-pea material and recommends washing the peas by immersion, spraying, or fluming to remove soil or grit. The presence of either type of contaminant may cause error in the Tenderometer reading or damage to the grid. The procedure recommended to member processors by Northwest Canners and Freezers Association (16) calls for a representative sample of 25 pounds from each lot of shelled peas, and a subsample drawn from the fanning mill of sufficient size to permit three or more Tenderometer cuts. If the range of the three readings does not exceed five units, the average is reported; otherwise, a second set of three readings is taken on a new subsample. A range of five or less units in the second set allows the average of the second set to be reported, and a range exceeding five units requires that the average of all six readings be reported. Twigg (19) advocated a variable sample size equal to one-half the square root of the lot by weight in order to provide equivalent sampling of small or large lots in Tenderometer tests. The importance of representative sampling of the lot was shown by Lee (10), who reported differences in Tenderometer readings as great as 30 units between samples drawn from a single point in a load of ungraded peas versus composite samples from seven random points in the load.

The question of washing peas and its effect on the Tenderometer reading was studied by the National Canners Association - Food Machinery Corporation Tenderometer Committee in 1952 (17). Results for replicated tests with four sweet varieties indicated an average increase in Tenderometer reading of 1.8 units for ungraded peas immersed in water for two minutes versus the dry peas at the same temperature. Although the difference was not conclusive on statistical grounds, it agreed with the increase of two Tenderometer units obtained in a similar study conducted during the 1952 season by a member company of the National Canners Association. The reason for the increase when peas were wetted was not investigated, but water hardness was discounted as a cause. Martin, Lueck, and Sallee (15) accounted for a 20-unit difference in Tenderometer readings between peas immersed in water versus dry peas on the basis of water hardness (340 parts per million).

Temperature of peas. Various investigators agree that the Tenderometer reading increases with a decrease in temperature of the peas. Martin, Lueck, and Sallee (15) observed an increase of one unit for each 3° to 4° F drop in temperature on both sieve 2 and sieve 4 Alaska peas. Kramer (8) noted an increase of one unit for each 5° F drop in temperature. Campbell (3) investigated the relationship between the Tenderometer reading of Tall Alderman peas and the temperature of the sample. Results showed an increase of one unit for each 4° F drop in temperature for peas of both low and high maturity. An increase of one Tenderometer unit for each 5° F drop in temperature of peas in the 85 to 120 Tenderometer range was reported by the NCA-FMC Tenderometer Committee (17). It is apparent that wide fluctuations in temperature of peas, as between day and night deliveries in many areas, can materially affect the accuracy of Tenderometer readings and of the grade assigned. Armed with the data, the investigators advocated control of the temperature effect either by tempering all samples to a convenient temperature in a water bath before making the Tenderometer cut, or by applying a temperature correction factor. However, it has been pointed out by several workers that the relationship between temperature and the Tenderometer reading is not a linear one; thus a correction factor should not be assumed to be constant over a wide range of temperatures. Although control of this variable seems to be important to Tenderometer reliability, temperature adjustment of the sample has not been adopted by the industry.

Sieve size of peas. Martin, Lueck, and Sallee (15) studied the relationship between Tenderometer value and sieve size of Alaska and several sweet varieties of peas. Results showed clearly that sieve size and toughness in peas increase together. Thus, the Tenderometer test on a pod-run sample of peas measures the combined effect of the average tenderness of each sieve size in the composite plus the proportion of the component sieve sizes in the sample. It would then follow that as the range of sieve sizes within a sample increases, the more variable will be the set of Tenderometer readings on the sample. Kramer and Aamlid (9) observed that the Tenderometer was less precise for the mid-maturity range of peas than for either end of the range. They reasoned that the middle range of maturity would tend to contain peas at all stages of maturity and would therefore lack the uniformity of the low-maturity lots (all tender peas) or high-maturity lots (all hard peas). The inference from these reports is that the Tenderometer reading for an ungraded sample is a weighted average reflecting mostly the maturity of the peas present in the greatest proportion. The accuracy of this reading will decline as the difference in tenderness between the several sieve sizes in the sample increases. Researchers (15, 24) have shown that more accurate Tenderometer readings can be obtained by measuring the sieve sizes separately; however, this method becomes lengthy and often impractical for routine grading.

Wear or damage on Tenderometer grids. The 1953 Supplement Sheet of the FMC Tenderometer Service Manual (4) recommends that the Tenderometer, or at least the grid units, be returned to the FMC factory every two years for overhaul and recalibration to a master FMC instrument. This recommendation followed the NCA Tenderometer Sub-Committee Study of 1952 (17), which demonstrated that wear in the grids and head parts caused low Tenderometer readings. Grids in which the average blade thickness was 0.004 inches below the nominal thickness of new blades (0.109±0.001 inches) were found to give low readings. Wear also reduced the grid contact surface area, and this played some part in lowering the Tenderometer reading. However, Graham and Evans (5) reported that blade wear, and blade rub due to distortion of the grid blades, can both upset the Tenderometer readings and render the FMC mechanical standardization procedure quite unreliable. Because wear or distortion of the grids will cause one Tenderometer to respond differently than another to a given sample of peas, processors have been advised through the FMC manual to protect against wear or damage to the grids by careful inspection and washing of all samples before testing by the Tenderometer. The effect of distortion in the grid blades beyond the FMC manufacturing tolerance (true to a plane within 0.001 inch) was not determined in the study.

Sample by volume or weight. Martin (14) compared the precision of Tenderometer readings resulting from weighed samples versus those produced from samples measured by volume. The average deviation for a set of 10 Tenderometer readings using a weighed 4-ounce sample was found to be very close to that of the corresponding readings where the grid pocket was filled and automatically leveled by closing the pocket cover. Since both methods showed an average deviation of about 1% of the mean Tenderometer value, Martin concluded that the volume method was valid and could be carried out automatically with less possibility of operator error. The approximate weight of the volume-measured sample was 5.7 ounces. Graham and Evans (5), using thawed quick-frozen peas as test material, indicated that more consistent readings were obtained by using a constant sample weight of 5 ounces rather than the approximately constant volume secured by filling the grid pocket. Whether or not weighed samples were used for routine maturity grading of raw peas was not indicated.

Time between harvest and Tenderometer test. The time of holding the peas, either in the vines after harvesting or in the shelled condition between viner and plant, can amount to many hours for some processing operations. Martin, Lueck, and Sallee (15) reported studies which showed that peas, whether held in the vines or in containers after vining, became progressively tougher over a period of 17 hours. The increase in toughness was measured in Tenderometer units and confirmed in the canned product by AIS determination. Campbell and Diehl (2) noted an increase of three to six Tenderometer units in raw freezing peas held three hours after harvest. Boggs, Campbell, and Schwartze (1) reported that a delay of three to six hours at 75° F for vined peas caused the skin to toughen to the same extent as an increase in maturity from 102 to 118 Tenderometer units.

Other Methods for Maturity Testing of Raw Peas

Objective methods suitable for the routine maturity grading of raw peas are few. Changes in peas which relate to maturity development are size, tenderness, specific gravity, sugars, starch, and total solids. Any method designed to estimate maturity in peas through one of the above properties must correlate closely with the sensory appraisal of maturity to be valid. Makower (13), in her review of methods for measuring maturity in peas, notes that of the chemical constituents, only total solids and alcohol insoluble solids correlate well with organoleptic maturity. Yet both are too time consuming for routine raw-product testing.

Boggs et al. (1) concluded that size alone is unreliable as a maturity index, being influenced by many factors such as variety, harvest date, and fertility. Lee (11) found specific gravity an unreliable method for determining maturity of raw peas, apparently because of air and gases in the tissues. In addition to the Tenderometer, several mechanical devices which measure the tenderness factor by puncturing or shearing have correlated quite well with the sensory appraisal of maturity and should be mentioned. Kramer and Aamlid (9) compared the Shear-press, Texturemeter, and Tenderometer in respect to correlation of the tenderness readings on raw peas with AIS values and panel scores on canned peas. The correlation coefficients reported show that all three instruments were highly correlated with the AIS method and significantly correlated with the panel.

Correlation Coefficients (r), Raw Peas

	AIS		Panel	
	Alaska	Sweet Vars.	Alaska	Sweet Vars.
Shear-press	0.970	0.959	0.879	0.824
Tenderometer	0.979	0.966	0.885	0.830
Texturemeter	0.964	0.943	0.855	0.798

However, the Texturemeter, being a small multi-punch instrument with a hand crank rather than the constant rate mechanical force system of the others, was the least precise and would require nearly five times as much replication as the Tenderometer or Shear-press to achieve the same precision level. The Tenderometer correlated slightly better than the others in this study.

In 1950, Lynch and Mitchell (12) introduced the Maturometer as an instrument for maturity grading of raw peas. The instrument pierces a sample of 144 peas simultaneously by means of a battery of puncture pins set in a plate. By means of a hand crank, the pins are forced through individual peas in countersunk holes and the total force required to pierce all peas is registered. In reliability tests, the Maturometer showed high correlation with AIS of raw peas (r = 0.93) and AIS of canned peas (r = 0.98). A comparative study with a Tenderometer indicated that the two instruments had the same precision level in replicated tests. The Maturometer has the advantages of being light in weight (60 pounds versus 700 pounds for the Tenderometer), portable, and not dependent on a power source. It is a hand-operated instrument, however, and would be subject to more human error than the Tenderometer.

Lynch and Mitchell (12) also tested the Succulometer for use in determining maturity in raw peas. They found a high correlation ($r = -0.92$) between Succulometer values and the AIS results on peas, but they found the Succulometer method to be more lengthy and laborious than either the Maturometer or Tenderometer methods.

Of those maturity-evaluating instruments that have come to our attention in this review, none appear to be better suited than the Tenderometer for routine maturity tests on raw peas. The Shear-press equals the Tenderometer in validity, precision, automation, and rapidity. It is more versatile but a less rugged instrument for routine raw product grading than the Tenderometer.

Possibilities for Improving the Tenderometer Test

It is unlikely that any mechanical or other objective test of maturity in peas will have unquestioned reliability and be completely satisfactory to all users. The fact that the pea processing industry has continued to use the Tenderometer increasingly over the past 30 years to establish maturity grades on raw peas as a basis for grower payment plus the evidence provided by the various sources cited in this review indicate that the Tenderometer is one of the most reliable and generally useful instruments available for testing maturity in peas.

Yet Tenderometer tests are subject to inconsistencies which give rise to questions about the reliability of the Tenderometer. Results for the same lot of peas may differ from one instrument to another, and two samples from a lot may test differently on the same Tenderometer. It has been shown in this review that these inconsistencies can be related to variability in the lot, to variability in the test conditions, or to variability between instruments. Therefore, any program designed to improve the accuracy of the Tenderometer test must deal with the problem of variation in each of these three areas. Since uniformly representative samples of the lot are a basic need for the reliable Tenderometer test, the program should logically begin with a study of sources of sample variability and development of sampling methods which will assure representative sampling. Subsequent investigations dealing with the influence of variations in test instruments and in test conditions could then be carried out more effectively. This review suggests that research undertaken in the following areas and in the order indicated would serve to increase the reliability of the Tenderometer test.

1. A study of sources of within-lot variation for small and large bulk lots of vined peas, including problems of stratification during filling into bulk carriers, or during wet or dry hauling. Development of sampling methods which assure representative test samples.
2. An investigation of sample characteristics and effect of within-sample maturity variation on the Tenderometer reading. Development of procedures to improve the accuracy of Tenderometer tests on more variable lots of raw peas.
3. Development of a positive method for standardizing the individual Tenderometer. An investigation of some of the newer synthetic materials might possibly yield a more stable and suitable standard than the various materials previously tested. A solution to the standardization problem may also be found in the application of some standard resistance mechanism such as a proving ring dynamometer or strain gauge to accurately measure the applied force. An engineering study could determine the feasibility of using the mechanism to register the amount of force necessary to displace the pendulum or the scale pointer a given distance.
4. Determination of the temperature effect on Tenderometer readings for varieties of canning and freezing peas grown currently in the Northwest states. Standardized procedures for temperature adjustment of raw pea samples also are needed.

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