MEASURING QUALITY OBJECTIVELY AND NONDESTRUCTIVELY

by
Alley E. Watada
Agricultural Marketing Research Institute
Beltsville, Maryland

Discusses the various tests currently used to measure quality of fruits and vegetables.

Quality can be defined clearly in communication only when the parameters constituting quality are identified and measured objectively. Most subjective measurements of quality are relative and the base used for measurement differs among people and changes unknowingly within an individual. These differences and changes cause uncertainty in the description of quality. Therefore, to develop a scale for different grades of quality, the factors constituting the quality need to be defined and measured objectively.

Factors considered under quality of fresh produce are observed in a sequence and can be separated into 3 groups. Factors that are noted initially are those which are judged by sight. These include composition, color, defects, and size. The second group, which includes hardness and firmness, is judged when the item is touched by hand. These attributes are vulnerable at the retail level in that repeated handling and measurement during distribution hastens softening or loss of firmness. The third group of factors is judged when the commodity is consumed. These factors, which include texture, flavor, aroma, and taste, have received the least attention because satisfactory objective methods of measurement are not available.

Current objective methods of measuring quality do not necessarily measure the attributes directly. Firmness, hardness, external defects, and external color are measured directly. On the other hand, flavor, taste, aroma, internal defects, and state of maturity commonly are determined by measuring associated changes within the commodity. For example, flavor, aroma, and taste often improve with advanced physiological age or maturity and concomitantly the composition of the colored pigments and density undergo correlated changes. Thus, color and density are used as criteria for measuring some of the sensory qualities, including those which can be measured directly. The color and density of a tissue are altered by pathological infection or physiological disorders; thus, these defects also can be measured indirectly by measuring the internal color.

Firmness or Hardness

The easiest and quickest method to measure firmness is by feeling the product by hand. This indicates firmness to the individual but the measurement cannot be described concisely. In addition, each time a commodity is tested for firmness, the stress caused by the pressure of the hand weakens the tissue, hastens the softening process, and shortens the shelf life.

The first mechanical device for measuring firmness was a puncture device developed in 1919 (10). Magness and Taylor (12) modified the device and engineered a portable spring-load pressure tester for measuring the puncture resistance of apples. This instrument measures firmness by recording the amount of force required to depress a plunger 7/16 of one inch in diameter into an apple for a distance of 5/16 of one inch. The Magness-Taylor pressure tester has been modified and is presently used as a standard firmness measuring device by the United States Department of Agriculture for estimating the picking quality, texture, and potential storage life of fruits and vegetables.

Texture or firmness needs to be measured nondestructively in many situations. The earliest method involved a measurement of pressure required to compress a commodity for a given distance by a flat-surface plate (14). This technique has been modified considerably since 1930 and current manually controlled instruments measure firmness either by a single-point (9) or a multipoint compression (11). Electronically controlled instruments minimize human error and also record the deformation curve of a sample. The deformation curve is informative in interpreting the texture and firmness of a sample. The speed of such instruments is too slow for industrial use.

Other techniques and principles are being explored for use in high-speed nondestructive measurement of firmness. Perhaps the most promising technique involves the use of random vibration. The vibration test was first introduced in 1942 (6) and the technique was pioneered by Abbott et al (1) and Finney and Norris (8). Finney (7) indicated that on the basis of frequency response curves, a 1/3-octane measurement of the accelerometer signal at 2000 Hz would be sensitive to differences in peach firmness. He found that the random vibration signal at 2000 Hz ranged from 45.3 to 73.3 dB for peaches that ranged from 0.9 to 22.4 pounds, which was measured by a 5/16-inch diameter Magness-Taylor probe mounted in an Instron testing machine. On the basis of his data, the vibration signal might be used to separate peaches as follows: fruits with a vibration signal exceeding 64 dB would be eliminated due to immaturity; those exhibiting 60 to 64 dB would be ideal for long-distance shipment; and those with a signal of 57 to 60 dB would be considered too soft for shipment but could be used locally. Fruits having a vibration signal of 40 to 50 dB would be optimum for consumption. These values should not be considered as the final separation point of the different groups until all the variables involved in fruit softening are studied completely; nevertheless, the technique has potential for use on mechanical harvesters, production-area packing lines, and perhaps in terminal market prepackaging plants.

Color

External color is a good indicator of eating quality for some commodities and commonly is measured by the reflectance technique. Most laboratory model instruments are capable of measuring the lightness, redness or greenness, and yellowness or blueness of a color. Commercial model instruments generally measure only a specific color and the measurement indicated on the instrument is derived differently with each instrument. The reading of an instrument used to determine raw tomato juice color is a product of an equation, which utilized all three measurements described for the laboratory model. Instruments used to determine the color of citrus, apples, potatoes, and tomatoes give the reflectance measurement at a specific light wavelength or the difference of measurements at two wavelengths. The potential of the reflectance instrument differs with each commodity.

Quality of all items cannot be categorized satisfactorily on the basis of external color. The use of external color as a criterion of quality is difficult when it is not uniform or is mixed with streaking or speckling of other colors. In some commodities, pigments in the epidermis mask internal color, and consequently, the external color gives a deceiving appearance of the fruit color. In most commodities internal color is a better index of quality than external color.

The internal color of a commodity can be measured nondestructively by light transmittance. This technique depends on the absorption of the light by chlorophyll (green), carotenoid (red and yellow), anthocyanin (red and blue) and other pigments in the tissue. Commodities differ in pigment composition; thus the wavelength that is used for light-transmittance measurement differs with the commodity. Several reports have described this technique to measure internal quality or maturity.

A current laboratory model instrument, termed the "Light-Transmittance Difference Meter" (LTDM), measures the light transmittance or optical density at two wavelengths and indicates the difference between the two measurements. Maturity, quality, and defects were found to be correlated more closely to the difference in optical density of two wavelengths than transmittance measurement at a single wavelength.

Maturity of tomatoes can be determined by the use of the LTDM. With the instrument, the degree of ripeness of fruit which are green externally as well as of those that are red can be determined. Ripeness of a green tomato is determined by the ΔOD of 510-600 nanometers (nm) and ripeness of a red tomato is determined by the ΔOD of 600-690 nm. Currently measurement of internal tomato color is limited to laboratory studies; however, this principle could be applied and used commercially for separating tomatoes according to maturity. This method of sorting might be used on mechanical harvesters to eliminate immature fruit that will not ripen properly; in the packing shed to separate the green fruits into various maturity categories so as to have fruit that will ripen at a desired date; and in terminal markets to categorize the red tomatoes. If all fruits had uniform external color at the wholesale point, tomatoes could be resorted to estimate the shelf life of the fruit or to determine the temperature at which the fruit should be maintained to hasten or retard ripening.

The LTDM has been used in the laboratory to measure the quality of peaches. The eating quality of a peach, like many other fruits, improves with the decreasing green color (chlorophyll content) and the increasing ripe color. On the basis of this relationship, Sidwell et al (13) measured the chlorophyll content of the peach with the LTDM to determine eating quality. They found that the instrument reading (ΔOD of 695-725) ranged from 80 to −30 for fruit that had an eating quality score ranging from 4 to 50, with increasing score indicating greater preference. On the basis of these scores, peaches can be separated to about four quality groups with the LTDM. Before such quality categories can be formulated for commerical use, all the commercially grown varieties would need to be studied with the LTDM and the relationship between LTDM values and firmness determined. The latter is particularly important in that maturity is currently based on firmness.

The LTDM has been used for sorting Red Delicious, Golden Delicious, Stayman, Rome and Winesap apples into various categories of quality (2, 15). In these studies, fruit were categorized into 4 or 5 classifications with the LTDM and submitted to a taste panel for preference score. The tests showed a very close correlation in the ranking of eating quality as indicated by the machine and by the taste panel. Other laboratory studies also have been encouraging, thus USDA is coordinating a program to evaluate a commercial model for sorting apples.

The LTDM can be used to detect internal defects such as water core of apples. Water core is a physiological disorder in which watery tissue develop around the internal vascular bundles often near the core and during storage the water-soaked appearance may spread and eventually become visible externally. Birth and Olsen (5) found that optical density of water-core tissue differed from sound tissue. On this basis, the LTDM was used to measure the optical density of apple fruit suspected to have water core. They found that fruit free of water core had a ΔOD (750-810 nm) value exceeding 50, those with a slight amount of water core had a ΔOD value ranging from 20 to 40, and those with moderate to severe water core had a ΔOD value below 20. Since water core at harvest frequently is at an incipient stage, a sorter could be used to segregate water-core apples immediately after harvest.

Hollow heart of potatoes, an internal defect, can be measured with the LTDM by determining the ΔOD of 710-800 nm. Effectiveness of the instrument is dependent upon the discoloration of hollow heart. Birth (4) measured the ΔOD of Katahdin and Cobbler potatoes suspected to have hollow heart and cut the tubers to determine the degree of hollow heart. With Irish Cobbler potatoes, those without any hollow heart had a ΔOD reading ranging from -.09 to -.33 with the largest number of readings centered between -.20 to -.28. Those with a small cavity and slight discoloration had a reading ranging from -.33 to -.42. Potatoes with a medium degree of hollow heart had a reading ranging from -.36 to -.65. The largest proportion of these potatoes had a reading ranging from -.35 to -.48. The potatoes with a large degree of hollow heart had a reading of -.40 to -.80 with the largest group having a reading of -.50 to -.55. On the basis of this research, it is conceivable that the LTDM technique can be used commercially to separate potatoes with hollow heart from sound potatoes or to sort hollow-heart potatoes into different categories.

The LTDM also is used to measure oil, protein, and water content of soybeans (3). The potential for the LTDM to measure these factors in other material is excellent. Studies are being conducted to evaluate the applicability of the instrument to measure fat content in hamburger and other meat products.

Other objective tests, such as X-rays, can be used to measure quality; however, those listed here probably have the greatest potential application for commercial use. Although the current commercial use of these techniques is minimal, with the increasing need for objective measurements of quality and exploratory challenges initiated by the industry, advancement in the development of commercial instruments is anticipated.

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