New Application of Nondestructive Methods for Quality Evaluation of Fruits and Vegetables in Japan

Sumio Kawano

National Food Research Institute, Ministry of Agriculture, Forestry and Fisheries, Kannondai, Tsukuba 305–8642, Japan

Summary

Studies on nondestructive methods for fruits and vegetables started in the early 1970s in Japan. The main goal of the studies was measurement of surface color of the products using visible light. After that, many studies using delayed light emission (DLE), near infrared (NIR), fluorescence, sound response, and impact force response have been carried out to develop ways of detecting maturity, firmness, surface defects and other properties. Since the late 1980s, NIR spectroscopy has been studied for determining the chemical composition of many kinds of products such as peaches, Japanese pears, apples, satsuma mandarins and other products.

In my presentation, new application of nondestructive quality evaluation of fruits and vegetables, including (1) firmness measurement, (2) internal void and disorder detection, (3) color grading, (4) maturity detection, (5) sweetness sorting, and (6) other topics is explained.

Recent R&D on Novel Application of Nondestructive Methods

Research and development on nondestructive measurements of invisible surface bruise, freshness, firmness, internal physiological disorder, astringency, sugar content (soluble solids) and others have been carried out.

Invisible surface bruise and freshness

Uozumi et al. (1987) used a fluorescence technique to detect invisible surface bruises on satsuma mandarins. This method is based on the fact that the peel oil emerging from broken oil cells emits strong fluorescence under ultraviolet radiation, but the peel oil in the cell does not have such a phenomenon. Satsuma mandarins have many oil cells over the peel. If the damage on the peel has broken some oil cells, it is possible to detect the peel oil by measuring the intensity of fluorescence at 565 nm, which is a peak in the fluorescence spectrum. Since bruised fruits easily decay during the storage period, it is important to eliminate the bruised fruits, and it might be possible to reduce the occurrence of decayed fruits during the storage period.

Mr. Andou has taken many interesting pictures of fluorescence emitted from agricultural products. Fresh cucumbers have very strong red fluorescence, and fresh eggs have also the same phenomenon. This technique is useful for detecting freshness of agricultural products.

Firmness

Firmness (Hardness) is an important quality factor of fruits and vegetables. To measure firmness, a compression test using an Instron-type testing machine is a common method in the laboratory. However, this is not practical because it is needed to compress the products in order to apply force beyond a bioyield point.

Takao et al. (1988) have developed a fruit hardness tester which can measure firmness of kiwifruit nondestructively by applying compression force below the bioyield point. The tester is named “HIT counter” after the test terms of hardness, immaturity and texture. By just setting the product in the tester, the amount of change in shape is measured and a digital reading within a few seconds.

A hand-held type of “HIT counter” has also been developed. Being different from existing testers, this tester is helpful in deciding the appropriate time for shipment and readiness for eating. By just touching the product and applying a pressure with a spring, the change in shape is measured on the dial gauge.

A prototype on-line fruit hardness sorting machine has also been developed based on the “HIT counter.” Using this sorter, kiwifruits can be sorted into three grades such as “overripe”, “ripe” or “immature”. The sorting rate is 3 fruits/sec.

Internal physiological disorder

Pineapple is one of the fruits of which the internal quality is hard to evaluate using the external appearance because the surface color is not directly correlated to the internal quality. Takao et al. (1991) are working on a visible transmittance method to detect physiological

This paper was presented at Session of Quality and Its Evaluation of Horticultural Products, the Commemorative Symposium of the 75th Anniversary of Japanese Society for Horticultural Science held on 3rd and 4th of April, 1998.

disorders in pineapples. A 100 W halogen tungsten lamp is used as the light source. The light transmitted through the product is detected by a photo multiplier to measure the light intensity and a sensitive CCD camera is used for image processing.

When the transmitted light intensity is very low the fruit has internal browning or is immature. When the intensity is very high the fruit has water core or is overripe. When the intensity is moderate the fruit is mature one. Using these images, maturity of pineapples can be detected.

Astringency

Persimmons taste astringent because they contain soluble tannin. However, if the astringent persimmon is treated with carbon dioxide to change the tannin from soluble to insoluble, the persimmon become sweet. The flesh of the sweet persimmon changes its color with black specks of insoluble tannin. The black specks reduce the transmitted light. Therefore, it is possible to detect astringent fruits by examining the light transmitted through the fruit.

Akimoto (1996) has developed a portable persimmon astringency detector as shown in Fig.1. The detector is simple and consists only of a halogen tungsten lamp. By placing the fruit on the top of the light source, the light transmitted through the fruit can be visually observed. When the fruit is astringent, the transmitted light is strong and bright. When the fruit is not astringent, the transmitted light is weak and dark.

Sugar content (soluble solids)

Methods based on near infrared spectroscopy have been studied in the USA for determining the dry matter of onion and soluble solids of cantaloupe. In Japan, this kind of research has been conducted mainly in the National Food Research Institute (NFRI) or in some

Fig. 1. Persimmon astringency detector(Akimoto, 1996).

Fig. 2. Sample presentation of peach for NIR measurement.

local agricultural experimental stations. In the NFRI, commercially available NIR instruments have been modified geometrically for adaptation to the measurement of NIR spectra of intact fruits and vegetables.

Kawano et al. (1992) used an NIR instrument with fiber optics in the interactance mode for determining sugar content in intact peaches. A schematic of sample presentation for NIR interactance measurements using fiber optics is shown in Fig. 2. A commercially available "Interactance Probe" with a concentric outer ring of illuminator and an inner portion of receptor, was used as the fiber optics. A cushion made of urethane foam was pasted on the end of the probe to hold a sample. The NIR measurement was performed by placing a sample on the end of the probe. As a result of multiple linear regression analyses based on NIR spectral data and chemical data of Brix value, high correlations between NIR Brix value and actual Brix value were obtained. The highest multiple correlation coefficient (R) was 0.97

Fig. 3. Sample presentation for making NIR transmittance measurements of satsuma mandarin.

with a standard error of calibration (SEC) of 0.48 Brix. The standard error of prediction (SEP) and bias were 0.50 Brix and 0.01 Brix, respectively. It is concluded that this method has an acceptable accuracy for nondestructive measurement of sugar content of peaches.

Using the interactance method, it was hard to determine the composition in fruits such as satsuma mandarins, which have thick peel. Therefore, a NIR transmittance method was used. A schematic for sample presentation is Fig. 3. The top of the sample was illuminated by monochromatic light through fiber optics, and the amount of light transmitted through the sample was measured by a silicon detector located just below the sample. As a result of multiple linear regression based on normalized NIR spectral data and chemical data of Brix value, high correlations between NIR values and actual values could be obtained. The highest multiple correlation coefficient was 0.99 with a SEC of 0.28 Brix. The actual Brix value and NIR Brix value calculated with the best calibration equation using a prediction sample set are extremely close. It is concluded that the NIR transmittance method yields an accurate estimate of Brix value in intact satsuma mandarins (Kawano et al., 1993).

Practical Sorting Machine

Fruit grading machine

The fruit grading machine, which enables to detect color, defect, shape and size of products, was designed and developed in 1985. The grading machine consists of

Fig. 4. Sensor unit for detecting color, defect and shape of fruit.

a vibrator, a line-up brush, a sensor unit, a conveyor, and a data processing unit, etc. A schematic of the sensor unit is shown in Fig. 4. The sensor unit consists of one CCD color camera and paired mirrors which enable one to observe a near-total view of each product. The product is illuminated by several tungsten halogen lamps arranged around the product. The reflected images from the product are detected by the CCD camera. In the camera, each image is split into two component beams by a semi-transparent mirror. Each component is detected by a linear line-scan CCD sensor through a red filter, or through a blue filter. Each image taken by the CCD camera is divided into 8192 (64×128) small square pixels. The color of each pixel is classified into 64 color levels from green to red. The color of product is decided as averaged color of color histogram for all pixels. The area of surface defects is calculated from the number of pixels which have a lower intensity of reflected light than a threshold. It is possible to detect defects as small as about 0.3 mm diameter. Fruit size is determined as diameter or height of the product. The sorting rate is 5 fruits/sec/lane. This kind of sorting machine has been installed in many packing houses for sorting satsuma mandarins, tomatoes or persimmons, for example. The machine enables the products to be sorted automatically and simultaneously in terms of surface color, defects, and shape or size (Maeda, 1987).

Internal void sorting machine

In 1986, Maki Manufacturing Co., Ltd. developed and introduced the first internal void sorting machine for watermelon. Watermelons selected by this machine are differentiated as "quality guaranteed". In the packing house each watermelon is placed on a tray by hand. The tray moves into the detector unit. The sorting machine gives an impact to the fruit with a small hammer and then detects the impulse sound by using three microphones arranged around the equator of the fruit as shown in Fig. 5. The sound signals from the microphones are compared with each other by a computer program based on statistical calculations. If significant differences in

Fig. 5. Internal void detector consisting of a hammer and three microphones.

shape and phase of the signals exist, the fruit is graded as "an internal void fruit". Inspection of each fruit is made automatically in about 3 sec. The sorting machine which has 3 of these units installed has a sorting rate of 1 fruits/sec.

Sweetness sorting machine

In 1989, Mitsui Mining and Smelting Co., Ltd. developed and introduced the first operational nondestructive automatic peach sweetness sorting machine. Peaches sorted by this machine were differentiated as "sweetness guaranteed". The company has now developed the multi-purpose sensor (MPS) for grading apples and Japanese pears in addition to peaches with a single unit.

When fruits on a line-up conveyor are illuminated by two focused tungsten halogen lamps, the scattered reflected radiation is measured by the MPS unit. The reflected radiation is converged by a lens and projected on a spectroscope to extract required wavelength and intensity data. The intensity of the radiation at respective wavelengths is measured by the line sensor (Fig. 6). The sugar content of a peach is calculated from the measured reflection intensity of NIR radiation by using a statistically developed calibration equation. The sorting rate is 3 fruits/sec/lane.

If the MPS system is introduced to packing houses, taste-oriented grading will become possible. If the quality data from the MPS system are correlated with data corresponding to the producing conditions (such as

soil conditions, and climate condition), guidance for producing high-quality products will be possible.

At present, some types of sweetness sorting machines are commercially available for peaches, apples and Japanese pears which have thin peel, or for satsuma mandarins which are fruits having relatively thicker peel, but relatively small in size. However, in the near future, a sweetness sorting machine for other products will become popular. And use of handy-type one will also be possible.

Conclusion

Nondestructive and precise evaluation of the grade-related quality of products, such as internal defects, internal injuries, and constituents will have very great ripple effects in marketing and farming.

Literature Cited

- Akimoto, K. 1996. Internal quality evaluation of fruits by visible light. p.52-59. In: G. G. Dull, M. Iwamoto and S. Kawano (eds.). Nondestructive quality evaluation of horticultural crops, Saiwai Shobo, Tokyo
- Kawano, S., H. Watanabe and M. Iwamoto. 1992. Determination of sugar contents in intact peaches by near infrared spectroscopy with fiber optics in interattance mode. J. Japan. Soc. Hort. Sci. 61 : 445-451.
- Kawano, S., T. Fujiwara and M. Iwamoto. 1993. Nondestructive determination of sugar content in satsuma mandarin using near infrared (NIR) transmittance. J. Japan. Soc. Hort. Sci. 62 : 465-470.
- Maeda, H. 1987. Grade and color sorter through image processing. Proceedings of international symposium on agricultural mechanization and international cooperation in high technology era. p.350-356.
- Takao, H. 1998. HIT counter. Noryu Giken Kaihou 108: 7-9. (In Japanese)
- Takeo, H. and S. Omori. 1991. Quality evaluation for fruits and vegetables using light transmittance. Noryu Giken Kaihou 145 : 14-16. (In Japanese)
- Uozumi, J., S. Kawano, M. Iwamoto and K. Nishinari. 1987. Spectrophotometric system for the quality evaluation of unevenly colored food. Nippon Shokuhin Kogyo Gakkaishi 34 : 163-170. (In Japanese)

Fig. 6. A multi-purpose sensor (MPS) for determining sweetness of peaches, apples, and Japanese pears.