

NONDESTRUCTIVE QUALITY EVALUATION TECHNOLOGIES FOR FRUITS AND VEGETABLES

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Summary

Safety and quality assurance in agri-products is being more crucial with the liberalized international trade system and globalization for capturing the global market. Many importing countries such as EU and Japan set up a relatively high quality/safety standard of the produce, requesting imported fruits to satisfy consumers demand. In order to strengthen the export competitiveness, adoption of advanced post-harvest technology is essential.

Quality components of fruits and vegetables are classified into the external such size, colour, shape, external defects etc. and the internal such as sugar content, acid content, firmness, maturity, internal breakdowns, etc. Difference in size and sugar content of Korean peaches which were harvested at the same area was introduced as an example for the necessity of grading. New sorting technologies using visible and near infrared (VIS/NIR) spectroscopy to evaluate internal quality of fresh products has been innovated for the past decade. Quality components included in grade standard and non-destructive technologies for measurement of those components are reviewed briefly. Particularly, features of on-line quality evaluation systems using VIS/NIR diffusive reflectance and transmittance were presented and a few tips to be considered in implementing them were discussed.

1. Introduction

Annual consumption of fresh fruits per person was increased more than twice for the past two decades in Korea and consumers' requirement for fresher and higher quality agri-produce is also increased with their per capita income.

Fresh fruits and vegetables have such a characteristic that their size, color, shape, chemical composition, etc. are different from each other even though they are the same variety and were harvested at the same place and time. Accordingly, sorting the fruits should be done one by one on individual basis to ensure the quality of commodity. To do so it takes a lot of manpower and time.

With consumer's desire for the better quality commodities and rapid expansion of international trade of agricultural products, a marketing policy to ensure the quality of agricultural products is being emphasized in Korea to promote the consumption of domestic products as well as to protect the domestic products from the imported. In order to fulfill the consumer's desire and socio-economic requirement, new technologies to evaluate the internal qualities of fresh products nondestructively have been developed and commercialized in Korea. The nondestructive methods could be divided into two types, that is, one is done at off-line state and the other is at on-line state. In other words, the former is a method free from the time limit in measurement of fruit quality and the latter is the one limited by time. To inspect all of fruits one by one, an on-line method having high sorting speed like 2 to 5 fruits per second should be developed.

Recently, image processing technology using CCD camera has been developed for evaluating appearance quality factors such as the size, color, shape, etc., and non-destructive technologies using VIS/NIR spectroscopy, sonic and ultra sonic, x-ray and MRI have been for internal quality factors such as sugar content, acid content, internal breakdown or cavity, etc.

In this paper, quality components of fruits and nondestructive technologies available for evaluating them were reviewed briefly. And recent developments of on-line sorting system using VIS/NIR spectroscopy will be introduced with a few tips to be considered for implementing optical sensing units.

2. Technology of Quality Measurement

2.1 Quality Component

It is hard to define quality of fresh fruits and vegetables because quality could be defined differently depending on consumer's preference, final utility, etc., but a standardization to identify the degrees of quality in a commodity is necessary for marketing of fresh products. The major quality factors of fruits and vegetables are reported as appearance, texture, flavor, nutritional value and safety as shown in Table 1.

The relative importance of each quality factor or component is depends upon the commodity and its intended use. Appearance factors have been the most important quality attributes for the fresh products before nondestructive assessment technology of internal quality was developed. Grade standards of commodity are established by country or by region to provide valuable tools in marketing of produce. Table 2 shows an example of quality components, which are included in grade standard of apple adopted in Korea, Japan and USA.

2.2 Necessity of Sorting/Grading

Quality is attributed to the several factors such as level of cultivation techniques, climatic conditions, soil condition, etc. Therefore, there is a wide difference in quality among products even if they were grown and harvested from the same area.

In 1999, *Chungdo Peach Experiment Station* harvested all peaches (*Miback variety*) from the three trees selected from three different locations, and measured their weight and sugar content. Table 3 shows distributions of weight and sugar content of those peaches. The weight was ranged from 140g to 450g, and it is noticed that the sugar content was

5.2 %Brix to 15.7 %Brix indicating a large variation of 2.6 to 7.5 %Brix within each weight class.

Table 1 Components of quality factors of fruits and vegetables.

External quality factors	Size (weight, volume, dimension)	
	Shape (diameter/depth ratio)	
	Color (uniformity intensity)	
	Defect (bruise, stab, spot)	
Internal quality factors	Flavor	Sweetness, Sourness, Astringency, Aroma
	Texture	Firmness, Crispness, Juiciness
	Nutrition	Carbohydrates, Proteins, Vitamins, Functional property
	Defect	Internal cavity, Water core, Frost damage, Rotten

Table 2 Quality components involved in grade standards of apple by country[14, 24]

Country	Quality components	
	External	Internal
Korea	color, shape, weight, freshness, scab sunburn, disease and insect damage, scars, pesticide damage, stem	sugar content, maturity, internal breakdown, internal browning
Japan	color, shape, weight, scab, sunburn, disease damage, insect damage, scar stem	maturity, internal breakdown, internal browning
USA	color, shape size, decay, scald, scab Jonathan spot, insect damage, freezing injury, russeting, scars,	maturity, firmness, internal breakdown internal browning, bitter pit, water core bruises

Table 3 Distributions of weight and sugar content of *Miback* peaches harvested from three trees selected

Weight		Substandard	Small	Medium	Large	Extra large
		less than 180g	180-210g	210-250g	250-300g	More than 300g
Size distribution (%)		3.0	7.7	25.3	40.5	23.4
Sugar content (Brix)	Min.	5.2	5.5	5.9	6.9	8.2
	Max.	7.8	10.1	11.2	12.7	15.7
	Average	6.6	7.7	8.5	9.4	10.8

Source: Annual Report of Chungdo Peach Experiment Station. 1999

Chungdo Peach Experiment Station also purchased 5 boxes of peaches in each price level from a wholesale market, and measured weight and sugar content of those peaches. Table 4 shows weight and sugar content distributions of peaches in each price level. It is also noticed that there is large difference in sugar content among peaches in the same priced box, ranging from 5.7 %Brix to 9.3 %Brix.

Table 5 is the result of survey to track the consumers' preference in purchasing peaches. Sweetness (47.3%), freshness (28.6%) and price (15.1%) are the most important factors, and especially, preference to sweetness is being increased a lot, showing decrease in price preference, as compared with the survey result conducted 5 years ago. The fruits having high sugar contents are much appreciated in the market, and consumers are willing to consider the quality more than the price.

Table 4 Size and sugar content distribution of peaches purchased from market

Price (Won/10kg)	Number boxes/peaches	Weight (g)			Sugar content (Brix)		
		Min.	Max.	Average	Min.	Max.	Average
Less than 20,000	5/194	205	310	251	4.5	13.8	9.0
20,000 - 25,000	5/152	265	400	324	7.1	12.8	9.4
25,000 - 30,000	5/138	300	440	352	7.1	13.3	10.0
More than 30,000	5/125	321	475	395	7.4	13.6	10.6

Source: Annual Report of Chungdo Peach Experimental Station. 1999

Table 5 Consumers' preference in purchasing fruits

	Flavor	Freshness	Price	Safety	Place origin	Size	Color	Shape	Nutrition
1998	29.0	27.2	26.5	10.0	-	2.4	1.2	0.3	3.5
2003	47.3	28.6	15.1	2.6	1.8	1.6	1.5	0.9	0.5

Source: Agricultural Outlook 2003. Korean Rural Economic Institute

Since large-scale world-famous discount stores have been introduced to Korean domestic market from the middle of 1990s, scales of domestic stores have been enlarged, and great progress and changes in post-harvest system have been made in Korea. To meet the markets' demand of high quality fresh fruits and vegetables, many modernized packinghouses, which is called as Agricultural Products Processing Centre (APC) in Korea, have been introduced to rural area

As the market becomes globalized and technology is being advanced, consumers' behaviour in purchasing farm products is being switched from quantity to quality with their increase in per capita income. In this frame, it is indispensable to develop and transfer quality evaluation technology to provide consumers with high quality/safety fruits and vegetables

2.3 Non-destructive Techniques for Measurement of Quality Components

Many kinds of nondestructive techniques have been developed to measure quality components of biological products including fruits and vegetables, and can be classified into optical, electromagnetic and dynamic methods according to their measurement principals. Table 6 is a summary of those techniques and quality components that could be measured with the corresponding technique. It is noted that most of the quality components listed could be measured at off-line state but not at on-line state on the spot.

Specific examples of practical use are (1) near infrared (NIR) reflectance/transmittance technique to measure soluble solid content of peaches, pears, apples, citrus, melon, and watermelon, (2) the acoustic response technique to evaluate the maturity and internal defects of melon and watermelon, (3) the electrical capacitance technique to estimate soluble solid content of watermelon.

Table 6. Non-destructive techniques to measure quality factors of horticultural produces.

Principals	Technique being used	Components
Optics	Image analysis	Size, shape, colour, external defects
	Reflectance, transmittance and absorbance spectroscopy	Colour, chemical constituents, internal defects
	Laser spectroscopy	Firmness, visco-elasticity, defects, shape
Dynamics	Vibrated excitation	Firmness, visco-elasticity, ripeness
	Sonic	Firmness, visco-elasticity, internal cavity density
	Ultrasonic	Internal cavity and structure, firmness, tenderness
	X-ray image and CT	Internal cavity and structure, ripeness
Electro-magnetic	Impedance	Moisture contents, density, sugar content, density, internal cavity
	MR/MRI	Sugar content, oil, moisture content, Internal defect and structure

On the other hand the magnetic resonance (MR) has been studied to measure the moisture and oil content of agricultural materials. The magnetic resonance imaging (MRI) was proved to be an extremely valuable technique to evaluate ripening, core breakdown, bruise, worm damage, chilling and freezing. Currently, MR and MRI are not practically used for routine quality testing, because equipments are too expensive and difficult to operate. However, MR and MRI techniques have great potential for evaluating the internal quality of fruits and vegetables.

Among the above techniques, NIR spectroscopic method has contributed to development and wide use of sorting and grading technology during the last 15 years. This paper describes the theory, application, examples of practical use, and some issues of near infrared spectroscopic method.

3. Principle and Application of VIS/NIR spectroscopy

3.1 Principle of NIR Spectroscopy

The electromagnetic radiation covers wide range of photon energies, and are generally divided into the following bands from the longest to the shortest wavelengths, radio wave, microwave, infrared, near infrared, visible, ultraviolet, X-ray and gamma-ray (Fig. 1).

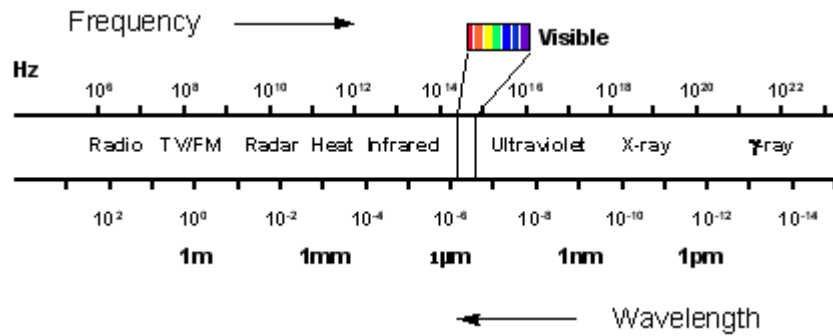


Fig. 1 Electromagnetic spectrum radiation

Optical properties are concerned with response of a matter to UV(180 nm–380 nm), VIS (visible: 380 nm-700nm) and NIR(near infrared: 780 nm-2500 nm) light, which are characterized by reflectance, transmittance, absorbance, or scattering . When a light beam falls on a biological object, part of the incident beam (about 4%) is reflected by the surface, which is called regular reflectance(or specular reflectance). Most of the incident radiation is transmitted into the cellular structure of the object. Of this portion, part is absorbed by the object, part is reflected back to the surface, which is called body reflectance or diffusive reflectance, and part is transmitted through the object. The absorbed radiation is transformed to other forms of energy instantaneously such as heat, chemical changes or other forms of radiation such as fluorescence and phosphorescence (Fig. 2). VIS/NIR spectroscopic method is attributed to the absorption phenomena of certain wavelength by certain molecules.

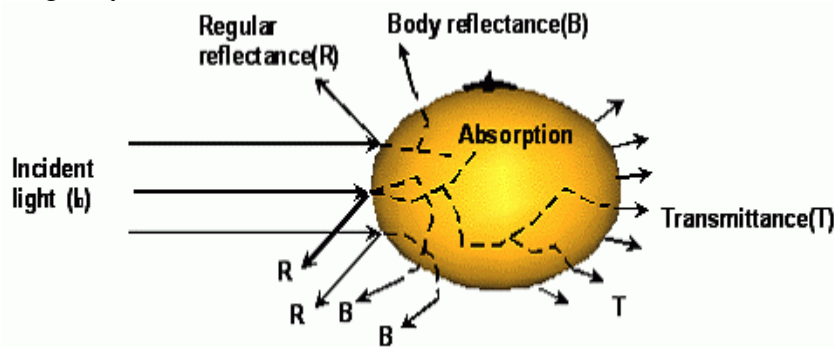


Fig. 2 Distribution of incident light on an object

3.2 Measurements and Analysis of Reflectance or Transmittance Spectrum Data

Optical devices to measure spectrum data are classified into reflectance and transmittance modes depending on the relative arrangement of light source, detector and object. In reflectance method, light source and detector are located at the same side as shown in Fig. 3. When lamps illuminate object, the diffusive reflected radiation is measured on wavelength scale by diode array sensor. A calibration equation to measure the target component is developed with those spectrum data sets, and validity of the equation is proved with the spectrum data sets of unknown samples. In developing the calibration equation, the raw spectrum data sets are pre-processed for reduction of noise, scattering effect, etc. which are caused by the difference in size and other physical properties of the given samples. Development of a robust calibration equation is an essential part of the non-destructive technique to measure the quality component.

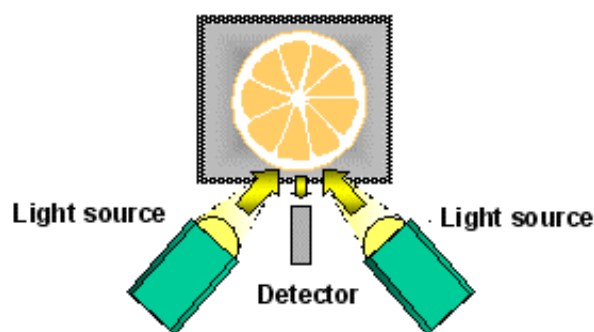


Fig. 3 Reflectance measurement system

Reflectance method can be used to measure the chemical constituents of the fruits and vegetables having relatively thin peel such as peaches, apples, and tomatoes, but this method is not useful for them having thick peel such as citrus, melon, and watermelon since penetration depth of the reflected light is limited to about 5 mm.

In summary, reflectance type has the following advantages and disadvantages as compared with the transmittance type.

- (1) Strong spectrum can be obtained at wider wavelength range.
- (2) Internal defects such as browning or rot can not be detected since the light is not penetrated through the whole fruit.
- (3) The measured value does not represent average of the target component because light illuminates local part of the sample only.

Transmittance method is to measure the lights transmitted through the object. Configuration of this method is classified into half transmittance and full transmittance depending on the arrangement of the sample, detector and light sources as shown in Fig. 4 and 5. Full transmittance is usually applied to the fruits of relatively small size and soft tissue such as citrus and tomato. On the other hand, half transmittance arrangement is widely used for many types of fruits and vegetables such as apple, pear, melon, watermelon, etc., because high intensity of radiation can be made by placing several lamps around the sample.

The most important considerations in implementing transmittance type is to select a detector unit having high sensitivity, to collect and deliver the diffusive transmitted light to the detector as much as possible, and to block the stray lights from the light source not to reach the detector. Slit size and number of grooves in a grating are related to intensity and resolution of spectrum. Usually, slits size of greater than 100 μm and gratings having less than 600 lines/mm is adoptable for transmittance measurement. Fig. 6 is a free tray that was designed to block the leakage of stray light between the contact surfaces of fruit sample and the tray. Concentric stairs are grooved inside the tray and ring-shape silicon pads are put on them to block the leakage of stray lights.

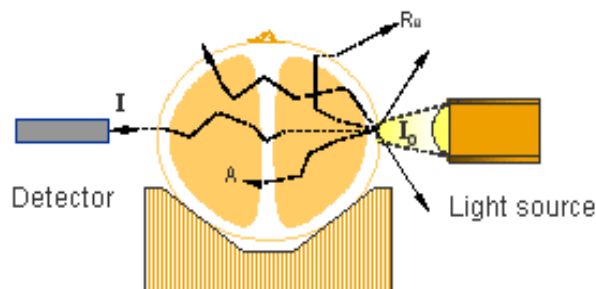


Fig. 4 Measurement of full transmittance

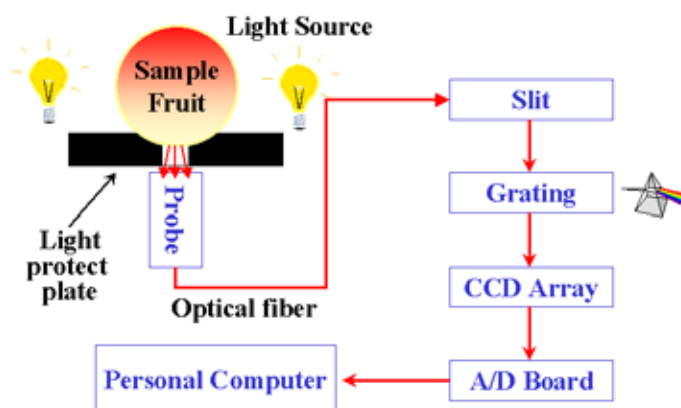


Fig. 5 Measurement of half transmittance



Fig. 6 A free tray for blocking light leakage

In summary, the transmittance type has the following merits and demerits:

- (1) Internal defects such as browning, breakdown etc. can be detected.
- (2) The measured value can represent average of the target component.
- (3) S/N ratio of the spectrum data is relatively low.
- (4) Leakage of stray light must be blocked.

3.3 On-line Applications of VIS/NIR Spectroscopic Method

Regarding to on-line prediction of sugar contents of intact fruits, Kawano described that in 1989 Mitsui Mining and Smelting Co., Ltd.(Mitsui Kinzoku Co.) in Japan developed and introduced an on-line sugar-sorting machine for peaches based on NIR reflectance method. The geometry of the optical part was composed of two focused tungsten halogen lamps for illumination, a lens for collecting the reflected light from the sample and a spectroscope having a diode array detector. Sorting rate was 3 fruits per second and the sugar content of each peach was predicted from the reflected NIR radiation by using a calibration equation.

Thereafter, FANTEC Co. Saiga Co. and Mitsui Kinzoku Co. in Japan developed sugar-sorting machine using NIR transmittance method. The optical part of the machine developed by FANTEC Co. was constructed with ten tungsten halogen lamps set up around the equator of the fruit sample which is placed and moved on a free tray. And the light transmitted through the sample was measured with a fiber optic sensor unit which was placed underneath of the free tray. The other sorting machines developed by Saiga and Kinzoku were full transmittance type. While each sample is lined up and moving on a conveyor, equator part of the sample was illuminated by a focused tungsten halogen lamp

and the light transmitted to the other side of the sample was detected by a sensor unit. Details of the optical part and characteristics of detector unit have not been made public. In Korea Choi et al. developed an on-line sugar sorting machine in 1998 using reflectance spectrum data of Fuji apple which were obtained with a commercial real time spectrometer covering wavelength range of 500 nm to 1050 nm. Standard error of prediction (SEP) of the developed system was 0.78 %Brix at sorting speed of 2 fruits per second. In 1999, Hwang developed a transmittance type sugar-sorting machine which was constructed with free trays and an automatic free-tray feeder. Each sample placed on a free tray was fed onto the carrier by the feeder and was illuminated by two line-shape tungsten halogen lamps that were installed at both sides of fruit sample. The transmitted light through the sample was collected by the optical fiber probe which was set up underneath the free tray carrier. The spectrum range was from 500 nm to 1050 nm. SEP was reported to be 0.5 to 0.6 Brix % at sorting rate of 2 to 3 apples per second.

3.3.1 Current Status of Fruit Sorting Technology in Korea

Modernized packinghouses have been introduced to rural areas since 1992 in Korea with the government policy for innovation of post-harvest technology, particularly for modernization of marketing facilities. Earlier to that, small scale weight-sorting machines and drum-type shape sorters had been used at each farmhouse base.

In the middle of 1990's, a few large-scale color sorting and sugar sorting machines were imported from USA and Japan. A reflectance type sugar-sorting machine was imported from Japan in 1996 for the first time for sorting pear. Thereafter, for the past decade sugar sorter using transmittance spectrums were domestically developed, and supplied to packinghouses with government financial aids. As of the end of 2005 the non-destructive sugar sorting systems are operated at 98 packinghouses in total (73 for apple, pear and peach, 10 for watermelon, 8 for mandarin, 6 for Korean watermelon and 1 for tomato). Sorting speed of these systems is one to four fruits per second and SEP is known as 0.5 to 0.8 %Brix. Table 7 presents current sorting technologies available for major fruits and vegetables in Korea

Table 7. Current status of sorting technologies for fruits and vegetable in Korea

Fruits Quality Factor	Apple	Pear	Peach	Persi- mmon	Orange	Melon	Tomato	Korean melon	Water -melon
Weight	○ ¹⁾	○	○	○	○	○	○	○	○△ ²⁾
Size	- ⁵⁾	-	-	-	○	-	-	-	-
Color	○	○△	○△	x ⁴⁾	○	-	○	x	x
Sugar content	○	○	○	x	○	△ ³⁾	△	○	△
Acid content	△	△	△	-	△	-	x	-	-
Maturity	x	x	x	x	△	X	△	x	△
Firmness	x	x	x	x	-	-	-	-	-
Freshness	x	x	x	x	X	x	x	x	x
Internal breakdown	○	○	x	x	X	x	x	○	△
Water core	○	-	-	-	-	-	-	-	-
Sponge disor.	-	○	-	-	-	-	-	-	-

Note: 1) ○: Using at packing house , 2) ○△: Technology is available but has not supplied at packing house, 3) △: Under study for improving accuracy , 4) x : Has not studied. 5) - : Not regarded as quality factor

3.3.2 Peach Grading System Using VIS/NIR Reflectance Mode

Korean peaches have such a characteristic that the intact flesh is relatively soft and sugar content within in a fruit is different by two to three %Brix depending on the locations such as stem side, blossom side, equator part, etc. To minimize the damage which may occur during sorting process, a free tray-type sorting system was developed, and the optical devices were designed so that reflectance spectrums could be measured from both sides of a peach at one time when it passes through the illumination chamber on the tray (Fig. 7). Fig. 8 show the configuration of the reflectance probes made with optical fibres.

All grading results of each producer's products are saved in database and provided to producers so that those data could be used for producing better quality peaches. The MLR (multiple linear regression) model was adopted in developing the calibration equation to predict sugar content. Performance of the system showed determination coefficient (R^2) of 0.69, SEP (standard error of prediction) of 0.49 %Brix (Fig. 9) and sorting capacity of 7,200 peaches per hour. It was also noticed that accuracy of sugar content measurement was much improved by using two reflectance probes as compared with the grading system using one.



Fig. 7 Peach grading system by sugar content.

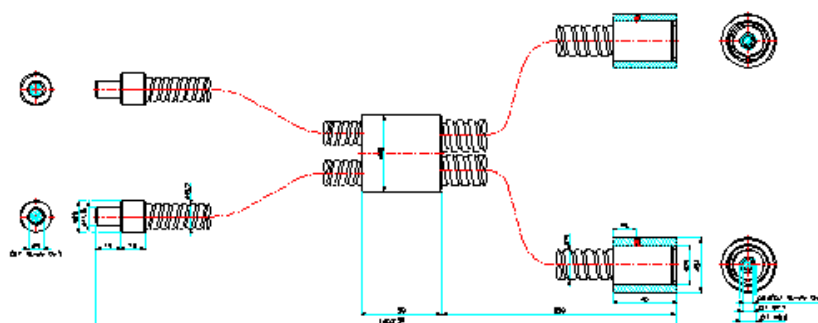


Fig. 8 Reflectance probes made with optical fibres to measure reflectance of both sides of an intact peach at one time.

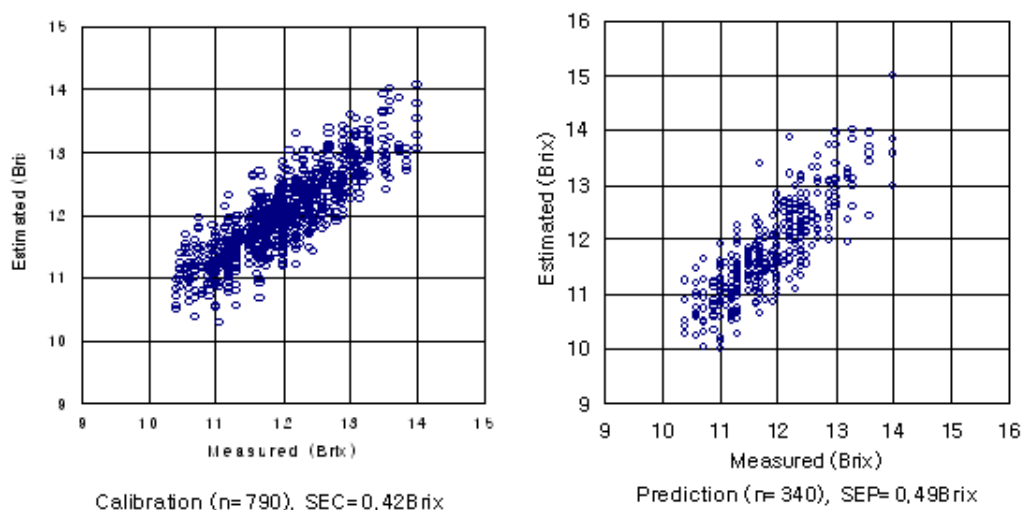


Fig. 9 Calibration and prediction results using MLR model

3.3.3 Citrus Grading System Using Full Transmittance Method

Conventional citrus sorters have been used for sorting citrus fruits based on size difference by using a series of rotating drums having different size of holes. With the requirement of internal quality evaluation of *Satsuma* mandarin produced in Korea, NIAE (National Institute of Agricultural Engineering in Korea) developed an on-line citrus sorting system which is composed of automatic feeder, grader and an automatic discharging unit. The grading unit was designed so that NIR spectrums of full transmittance could be measured (Fig. 10) from the citruses which were fed one by one into the illumination chamber by an automatic feeder. In taking the spectrum, it was observed that spectrum data is affected by the posture of the *Satsuma* mandarin which passing through the illumination chamber. To reduce such a variation in spectrum data, the automatic feeder should be designed so that those fruits are always placed flat on conveying belt.

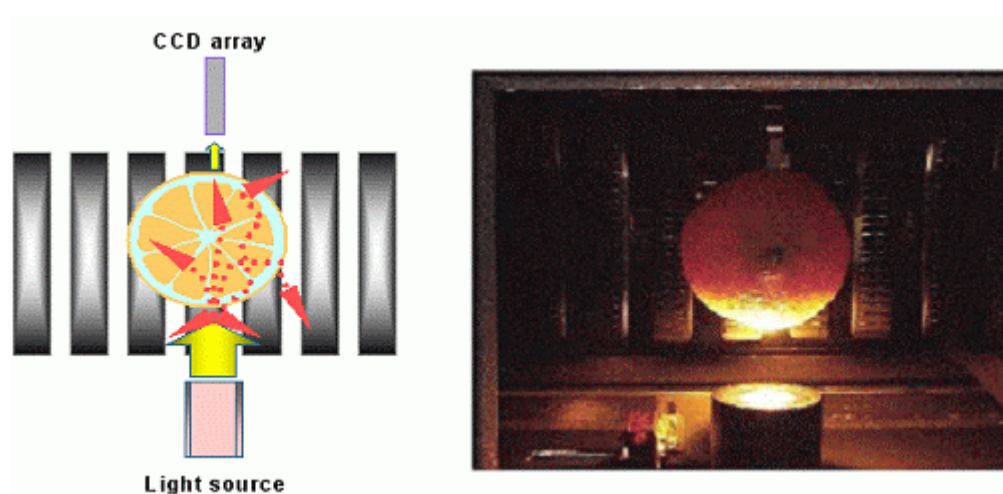


Fig. 10 Arrangement of light and detector for sugar sorting of *Satsuma* mandarin

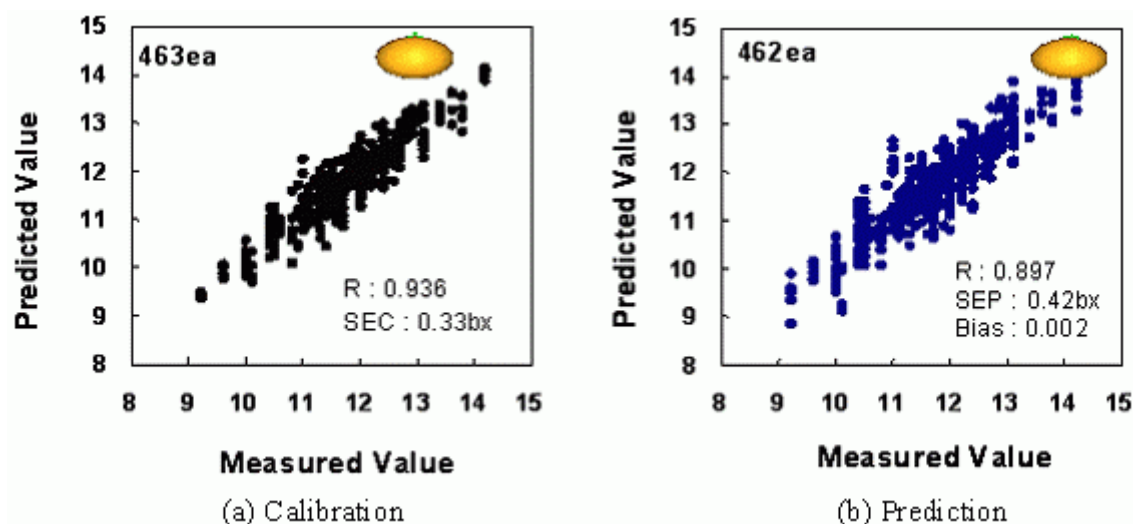


Fig. 11 Calibration and prediction results of sugar content in citrus by PLSR model.

Spectrum data were measured in wavelength range of 650 to 955 nm with a real time spectrometer (Ocean Optics, USA) having CCD array sensor of 2048 pixels. A 300 W halogen lamp and a lens assembly were used for strong illumination. For collecting and collimating the transmitted light, a probe was made with lens assembly and optical fibres. The calibration equations to estimate sugar content and acid content of mandarin oranges were developed, respectively, by using PLSR (Partial Least Square Regression) model. Calibration and validation results of the sugar content measurement model are shown in Fig 11. Sorting capacity was 10,800 citrus per hour.

3.3.4 Detection of internal Defects of Fuji Apple

Non-destructive technologies to detect internal breakdowns in Fuji apples, Korean pears and sweet potatoes have been developed at Seoul National University in Korea. In this paper, the result of study on detecting the internal rot (Fig. 12) and water-core (Fig. 13) in Fuji apples by means of VIS/NIR transmittance spectroscopy is introduced.

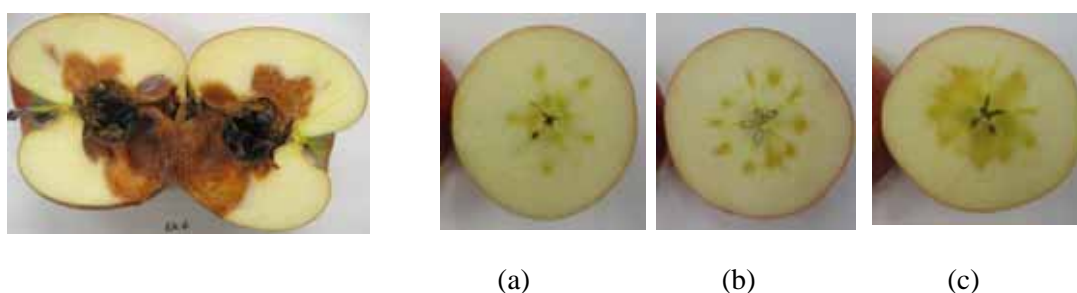


Fig. 12 Internal browning (or rot) of Fuji apple

Fig.13 Water-core of Fuji apples (a) minor, (b) mild and (c) severe

To acquire the transmitted energy spectra of an apple, a proto-type spectroscopic sensing unit was made with a sample holder, light sources, a real time spectrometer, etc as shown in Fig. 5. The apple samples having the internal rot were artificially made for test runs. All spectra of the Fuji apple samples showed three peaks near 640 nm, 710 nm and 800 nm, respectively, and the transmitted energy levels of the water-core apples were

generally higher than the sound. And those of the internally rotted samples were the lowest (Fig. 14).

Fig. 15 presents mean spectra of the normalized spectrum data with the lowest value near 675 nm. In this figure it is observed that the relative intensities of the water-core apples are more distinguished from the sound and the rotted than those before normalization. Classification analysis indicated that the most efficient classification algorithm is primarily to classify the internally rotted from the given Fuji apple samples by the peak difference values which were obtained by $|T_{710} - T_{800}|/T_{675}$ (Fig.16), and secondly, classify the water-core apples by the values of $(|T_{645} - T_{710}|/T_{675})$ (Fig. 17). With such an algorithm, CCRs (correct classification ratios) of the sound, the water-core and the internally rotted samples were expected to be 100 %, 91.4 % and 97.6%, respectively.

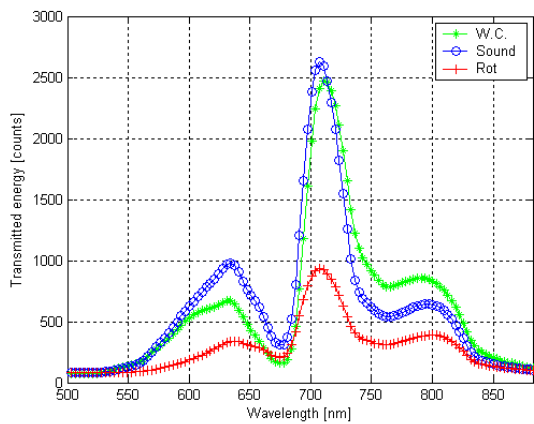


Fig. 14 Mean transmitted energy spectra of the sound, water-core and internally rotted Fuji apples

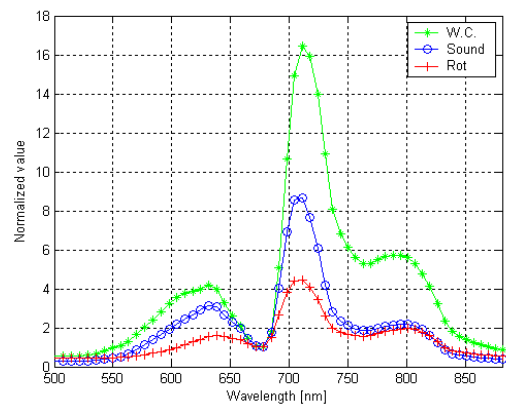


Fig.15 Mean transmitted energy of Fuji apples normalized with the lowest value near 675 nm

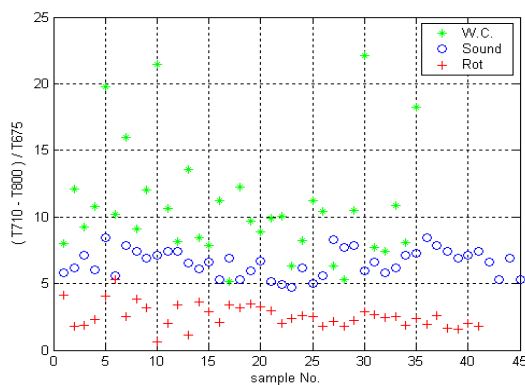


Fig. 16 Distribution of $(T_{710} - T_{800})/T_{675}$ of Fuji apples

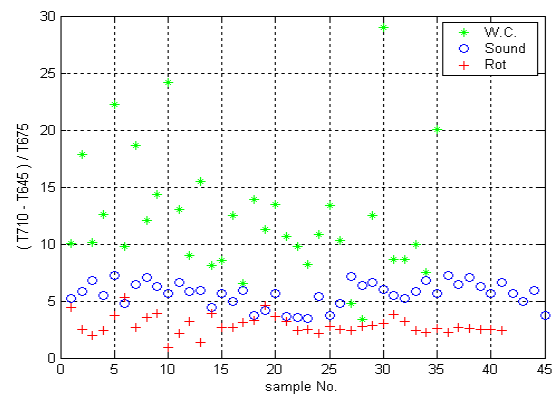


Fig. 17 Distribution of $(|T_{645} - T_{710}|/T_{675})$ of Fuji samples

3.3.5 Watermelon grading System Using Half Transmittance and Sound

The quality components of the watermelon are maturity, sugar content, inside cavity, yellow belt, blood flesh etc., but the quality grading is practically being done by inspector's sensibility or experience. A non-destructive watermelon sorting system which can grade the watermelon by weight, sugar content and internal defect was developed in Korea (Fig. 18). The sorting system adopts half transmittance method to evaluate sugar content, and acoustic method to evaluate internal defects. To get the transmittance spectrum from a watermelon, strong light source of 2.4 kW- tungsten halogen lamps was used, and PLSR method was for development of calibration equation of sugar content. Sugar contents could be estimated with the developed system in SEP of 0.8 %Brix.

The internal defect, mainly maturity and cavity, was detected by hammering the watermelon to generate the acoustic sound. The acoustic signals were measured from three points of a watermelon sample in the noisy packinghouse, which were processed for removal of noise and detection of the internal breakdown. Performance of this sorting system was sorting capacity of the 1,500 watermelons per hour, sugar content measurement error of ± 0.8 % Brix and 90.1 % accuracy of internal defects.

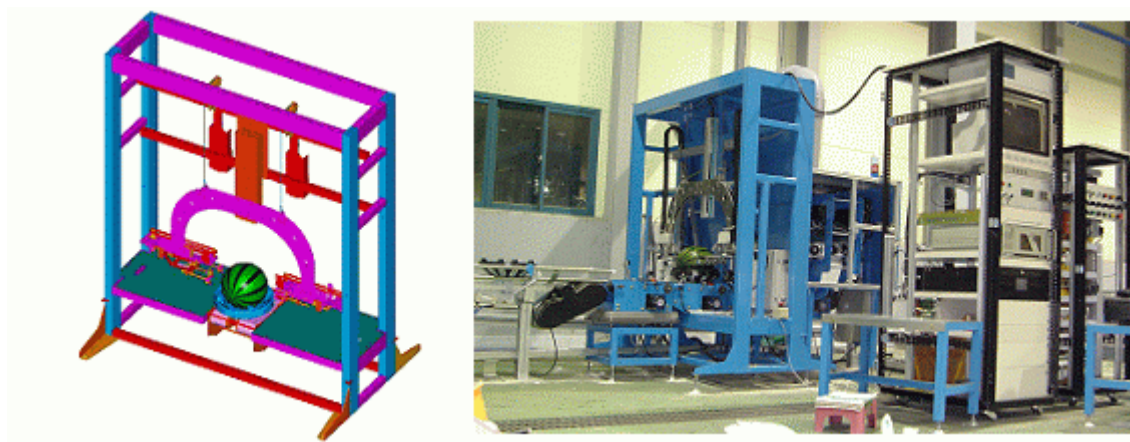


Fig. 18 Schematic diagram and photo of internal defect detection system using acoustic method

4. Conclusions and Remarks

Grade standards to identify quality of agricultural products have been established by country or by region. Quality components included in grade standards are composed of various external and internal factors, but fruit sorting at packinghouse has been actually done on the basis of external factors such as color, shape and size.

In 1989, on-line sugar sorting machine which using diffusive reflectance of peach was reported to be commercialized for the first time by a company in Japan, and in 1996 on-line quality evaluation techniques using the diffusive transmitted light were developed for sorting apple, pear and peach in Japan. The quality factors evaluated by the technique were not only sugar content but also acid content, maturity and internal defect, etc. Thereafter, application of this technique has been continuously extended to other fruits and vegetable such as citrus, persimmon, melon, watermelon, tomato, etc. It is reported that reflectance-type and transmittance-type fruit sorting units were also developed in Korea in 1998 and 2000, respectively.

Concerns in recent years are on development of preprocessing and regression analysis methods to get more accurate and robust calibration equations from the spectrum data sets, and quality components of interest are firmness, freshness, odor, taste, safety, etc.

With development of such a new technique, a few changes in production and marketing of fresh products have been occurred. Firstly, consumers' choice is turned from appearance qualities to the internal. Secondary, quality guarantee system is being more strengthened in domestic market and in international trade. Thirdly, marginal value of better quality products is increased and fourth, production and post-harvest technologies of fruits and vegetable are improved by producers.

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