THE NONDESTRUCTIVE MEASUREMENT OF THE SOLUBLE SOLID AND ACID CONTENTS OF INTACT PEACH USING VIS/NIR TRANSMITTANCE SPECTRA

I. G. Hwang[1], S. H. Noh[2], H. Y. Lee[2], S. B. Yang[2]

[1]Research and Development Institute of TONGYANG MOOLSAN Co. LTD.,
#378-1 Maeng-Ri Wonsam-Myeon, Yongin-Si, Kyunggi-Do 449-870, KOREA
[2]School of Biological Resources and Materials Engineering
College of Agriculture and Life Sciences, Seoul National University
Suwon, Kyunggi-Do 441-744, Korea
E-mail: hwangig@tym.co.kr

ABSTRACT

Since the SSC(soluble solid contents) and titratable acidity of fruit are highly concerned to the taste, the need for measuring them by non-destructive technology such as NIR(Visual and Near-infrared) spectroscopy is increasing. Specially, in order to grade the quality of each fruit with a sorter at sorting and packing facilities, technologies for on-line measurement satisfying the tolerance in terms of accuracy and speed should be developed.

Many researches have been done to develop devices to measure the internal qualities of fruit such as SSC, titratable acidity, firmness, etc. with the VIS(Visual)/NIR(Near Infrared) reflectance spectra. The distributions of the SSC, titratable acidity, firmness, etc. are different with respect to the position and depth of fruit, and generally the VIS/NIR light can interact with fruit in a few millimeters of pathlength, and it is very difficult to measure the qualities of inner flesh of fruit. Therefore, to measure the average concentrations of each quality factor such as SSC and titratable acidity with the reflectance-type NIR devices, the spectra of fruit at several positions should be measured.

Recently, the interest about the transmittance-type VIS/NIR devices is increasing. NIR light can penetrate through the fruit about 1/10～1/1,000,000 %. Therefore, very intensive light source and very sensitive sensor should be adopted to measure the transmitted light spectra of intact fruit.

The ultimate purpose of this study was to develop a device to measure the transmitted light spectra of intact fruit such as apple, pear, peach, etc. With the transmittance-type VIS/NIR device, the feasibility of measurement of the SSC and titratable acidity in intact fruit cultivated in Korea was tested. The results are summarized as follows;

A simple measurement device which can measure the transmitted light spectra of intact fruit was constructed with sample holder, two 500W-tungsten halogen lamps, a real-time spectrometer having a very sensitive CCD array sensor and optical fiber probe. With the device, it was possible to measure the transmitted light spectra of intact fruit such as apple, pear and peach. Main factors affecting the intensity of transmitted light spectra were the size of sample, the radiation intensity of light source and the integration time of the detector. Sample holder should be designed so that direct light leakage to the probe could be protected. Preprocessing method to the raw spectrum data significantly influenced the performance of the nondestructive measurement of SSC and titratable acidity of intact fruit. Representative results of PLS models in predicting the SSC of peach were SEP of 0.558 Brix% and R2 of 0.819, and those in predicting titratable acidity were SEP of 0.056% and R2 of 0.655.

Key Word : Non-Destructive, Intact Fruit, Real-Time, On-Line, NIR, SSC, Acidity, Measurement

INTRODUCTION

To access the qualities of intact fruit, external and internal quality factors should be determined simultaneously. The surface color, shape and size are the main factors related to external quality and sweetness, acidity and firmness are related to the internal quality factor. To sort fruit by its quality into several grades in sorting and packing facilities, these quality factors should be determined in a real time manually or automatically. External qualities such as surface color, size and shape can be determined by manual or image processing technology, but internal quality such as sweetness, acidity and firmness can not be determined manually.

Recently many researches have been conducted to develop a device to measure the internal quality factors using VIS and/or NIR reflectance/transmittance spectra(2,3,7,8). In the case of reflectance-type VIS/NIR sensor, it is difficult to determine the average contents of internal quality factors because their distributions are different in position and depth in inner direction of fruit. But in case of transmittance-type VIS/NIR sensor, it is easy to measure the average contents of internal quality factors using the several external lamps which are arranged uniformly around the surface of the fruit.

In case of conventional NIR spectrophotometer, light source can penetrate several millimeters into the flesh of intact fruit and the total amount of transmitted light is about 1/10～1/1,000,000 %, therefore it is needed the high sensitive sensor and the light source should be intensive enough to detect the transmitted light through the intact fruit. Recent researches show that it is possible to measure the SSC of peach using transmitted light spectra(5,6). In these researches, the light source was intensive and the angle between light source and the detectors was arranged 45°, and the detectors were contacted to the surface of fruit sample. In the sorting and packing facilities, fruits are conveyed fast and continuously, 1～5 fruits/sec, therefore in the design of the sensing device to detect the transmitted light which is very weak and time varying, several requirements should be satisfied as follows;

1. the sensor should accept a transmitted light in a real time

2. the light source should be intensive as possible as the sensor can detect the transmitted light

3. only the light which transmitted through the intact fruit should be accepted by the probe which is linked to the sensor, viz., the light leaking from the gap between the fruit and sample holder should be isolated from the probe.

4. the probe should be positioned apart from the fruit, but the distance between the probe and the fruit should be short as possible

We have been conducted a series of researches to develop a on-line sensor which can be implemented into the sorting and packing facilities. And this preliminary study is specially related to the design of on-line VIS/NIR transmitted light sensing device.

The objectives of this study are follows;

1. To develope a device which satisfies the above 4 requirements.

2. Using the transmitted light spectra of peach, the feasibility to measure the SSC and the acidity of peach was demonstrated.

MATERIALS AND METHODS

The cultivate of peach used in this experiment was Wolmee, and the number of peach sample was 55. Each peach sample was chosen with respect to the surface color from greenish to reddish so that the distributions of the SSC and titratable acidity were varied. The peaches were cultivated in Chochiwon city and harvested on 23, July in 1999. After harvest, peaches were stored in room temperature for about a day.

Transmitted light spectrum of each peach sample was measured twice with different position and direction with respect to the detector. After measurement of transmitted spectra of peaches, the soluble solid contents and titratable acidity of these samples were measured with digital refractometer(DBX-55, ATAGO, Japan) and automatic titratable acidity measurement system(AUT-301L, Japan).

In Fig. 1, the experimental apparatus for measuring the transmitted light spectrum of intact fruit was demonstrated. Two tungsten halogen lamps of which power were 500W respectively were arranged around the fruit sample. The optical fiber probe was positioned about 10mm below from the sample holder and the fruit sample(peach) was positioned upon the sample holder which was made of plastic tray and sponged material. The sponged material was designed to prevent the incident light from leaking out through the clearance between the plastic tray and the fruit. The center of the sample holder was holed, and the diameter of the hole was 40mm. The transmitted light, which penetrated through the intact fruit and then passed through the hole, finally reaches the probe. The light passed onto the probe was finally transmitted to the CCD detector of S2000-FL spectrometer(Ocean optics, USA) by the optical fiber. The width and height of slit in S2000-FL were 200μ m and 1000μ m respectively and the wavelength range was from 500 ~ 1100nm. The integration time of the CCD sensor was 50msec.

Water content in the peach is about 90%. And the rest is sugar, acid, fiber, and etc. The variation in the spectrum due to the sugars such as fructose, glucose and sucrose, and the acid such as malic and citrus is minor because the small difference in the water content and difference in pathlength due to the fruit size can change the spectrum extensively.

As the spectra of peaches were measured in a real time, about 50msec per peach, and the sample and the probe was not contacted, so the spectra was noisy, and the baseline and slope of peak in the spectrum changed sensitively when the fruit size was different or the position and attitude of fruit were changed with respect to the sensor.

To eliminate or reduce the noise in the spectrum, smoothing with Hanning window was applied, and to reduce the effect of scattering the smoothed spectra were transformed by SNV(Standard Normal Variate Transform) or/and MSC(Multiplicative Scattering Correction). And finally the smoothed and transformed spectra were differentiated into the 1st or 2nd order.

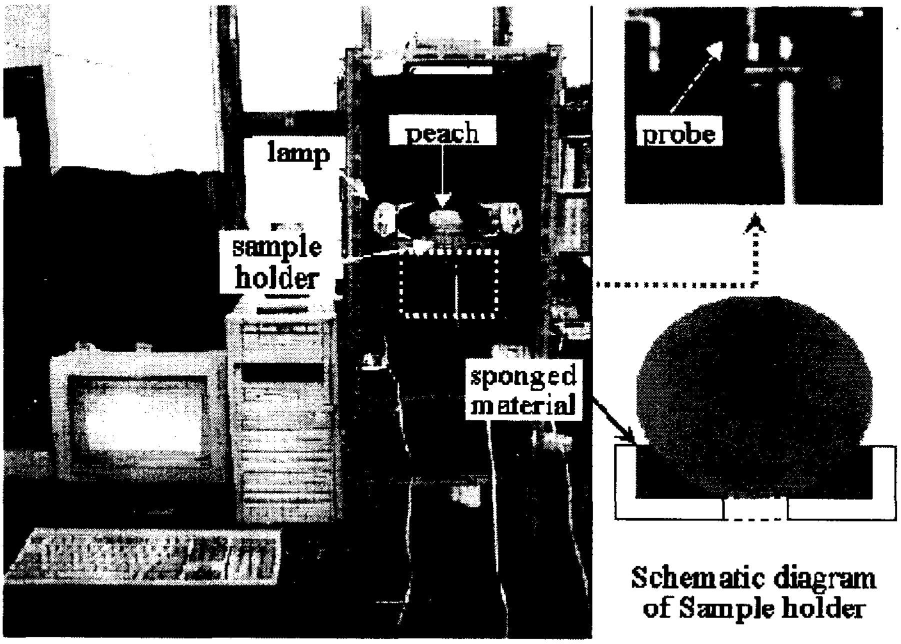

Fig. 1 An experimental apparatus for measuring transmitted light of intact fruit

RESULTS AND DISCUSSION

To investigate the feature of the spectra due to the difference in the SSC of intact peach, the 4 spectra of peaches with different SSCs were demonstrated in Fig. 2. In this figure, the SSCs of each spectra were 8.0, 10.0, 12.0 and 14.1 Brix%. And also, to investigate the feature of the spectra due to the difference in the acidity of intact peach, the 4 spectra of intact peach with different acidity were demonstrated in Fig. 3. In this figure, the titratable acidity of these peach were 0.296%, 0.432%, 0.568% and 0.704%. In

Fig. 2 and 3, the peak near 670nm was due to chlorophyll, and the peak near 760nm and 950nm were due to water. The peak near 840nm was not identified clearly. In the 550～670nm range, the variation of transmitted spectra was relatively large with respect to the other range because the surface color of the peaches were varied from greenish to reddish, therefore the spectra in this color region changed very largely. The inserted figure in Fig. 2 showed that the SSCs of peach were highly correlated with the surface color of the peaches. As the peaches mature, the surface color changes from greenish to reddish, and the SSC in intact peach is generally increasing, so the inserted figure in Fig. 2 coincides very well.

Fig. 3 showed that there existed spectral difference in the range of 600～830nm with respect to the difference in contents of acidity. Especially in the 670nm band, the spectral difference was apparent, and these results also showed that the contents of acidity and the chlorophyll were highly correlated also. It is known that 900～938nm range is related to the CH overtone, but in Fig. 2 and 3, the spectral value did not change with respect to the SSC or acidity, because in these spectral region the major factor which changes the spectrum largely is not the SSC or acidity, but rather the scattering effect which arises from the difference in fruit size and/or pathlength. The spectrum in this region changes more easily due to the difference in the size, surface color and etc. than the SSC and/or acidity in the intact peach.

The transmitted light spectra which were measured by the experimental apparatus in Fig. 1 changed more easily due to the difference in the external factors such as the size of fruit, the relative position to the probe with respect to the fruit and etc. than the differences in the SSC and acidity in fruit. And the spectra were measured in a real time, 50msec per fruit, so much noise was included in the spectra. To demonstrate the effect of the preprocessing of spectra, smoothing operation was conducted in raw transmitted light spectra with the Hanning window. The smoothed spectra with the segment size 0(raw spectra), 6.75nm, 26.02nm and 51.75nm were illustrated in Fig. 4. In this figure, the small fluctuations in the spectra assumed to be due to noise were reduced as the segment size increased, but increasing the segment size too large, the position of peak also shifted. In figure 2 and 3, the baseline of spectra with various contents of the soluble solid and acidity were varied and the slope of the spectra also different due to the effect of scattering. To reduce or eliminate the scattering effect, SNV and MSC were conducted in the raw spectra. In Fig. 5, the scattering corrected spectra by SNV and MSC, we can see that the scattering effect was reduced, consequently the variations in the spectra due to scattering were reduced.

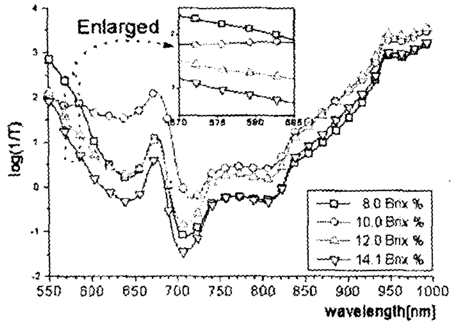

Fig. 2 Raw absorbance spectra of peaches with different Brix values

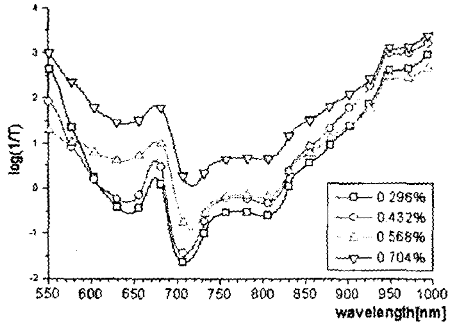

Fig. 3 Raw absorbance spectra of peaches with different titratable acidity

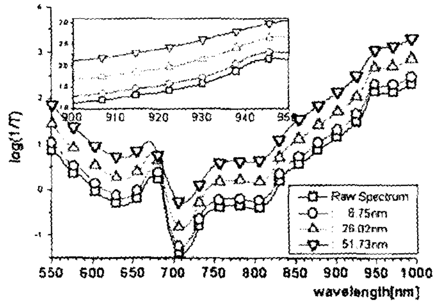

Fig. 4 Spectrum smoothing with Hanning window with different segment sizes

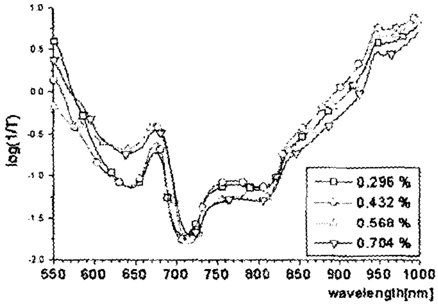

Fig.5 Scattering correction with SNV & MSC

Generally, to intensify the feature of the spectrum, spectrum derivative is conducted as preprocessing. Fig. 6 and 7 are the 1st and 2nd derivative spectra of raw spectra with different gap sizes. In these figures, by differentiating the raw spectrum, the features in the spectrum were intensified, but increasing the gap size too high, the derivative spectrum also smoothed.

To test the feasiblity of the prediction of SSC and acidity of intact peach using the transmitted light spectra, the 110 spectra were divided into 2 sample lots, one is for calibration, the other is for validation. Several calibration equations were constructed using PLS model with different preprocessing conditions, various smoothing sizes, executing or not executing SNV and/or MSC, and 1st or 2nd derivatives of spectra with various gap sizes. The performance of calibration equation was tested using the validation data set by SEP(Standard Error of Prediction) and determination coefficient(R2). The segment and gap size in smoothing and 1st derivative for the best performance in the case of the SSC prediction were 32.45nm and 8.03nm respectively. With that smoothing and derivative condition mentioned above, the SNV and MSC also conducted, the SEP and R2 for predicting the SSC were 0.558 Brix% and 0.819 respectively. The SEP and R2 for predicting the acidity were 0.0555% and 0.655 when the smoothing size was 0.32nm, SNV and MSC were conducted, and the 1st derivative(40.16nm) was finally conducted.

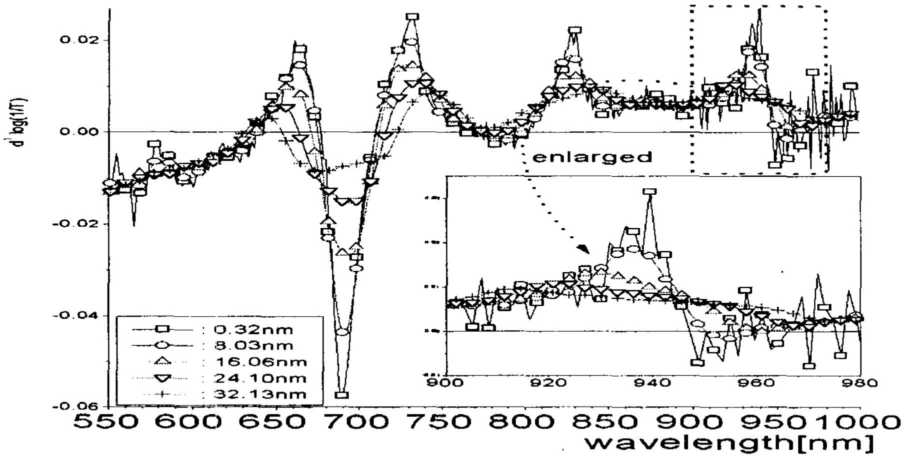

Fig. 6 1st derivative spectra of raw spectrum with different gap sizes

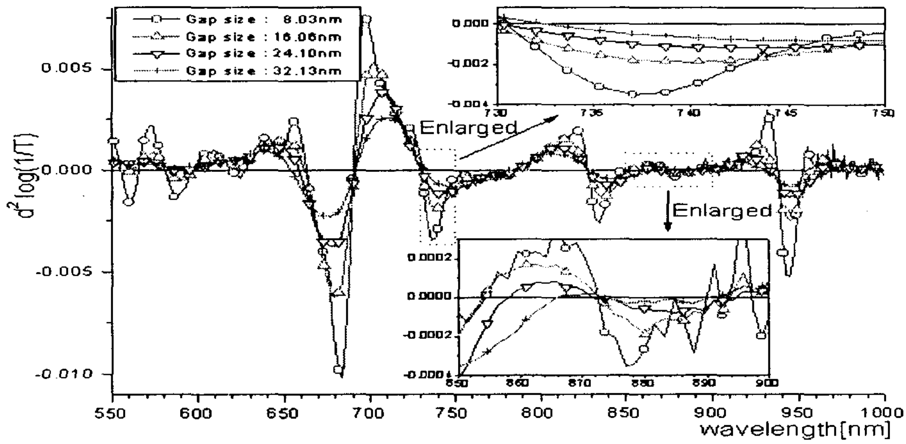

Fig. 7 2nd derivative spectra of raw spectrum with different gap sizes

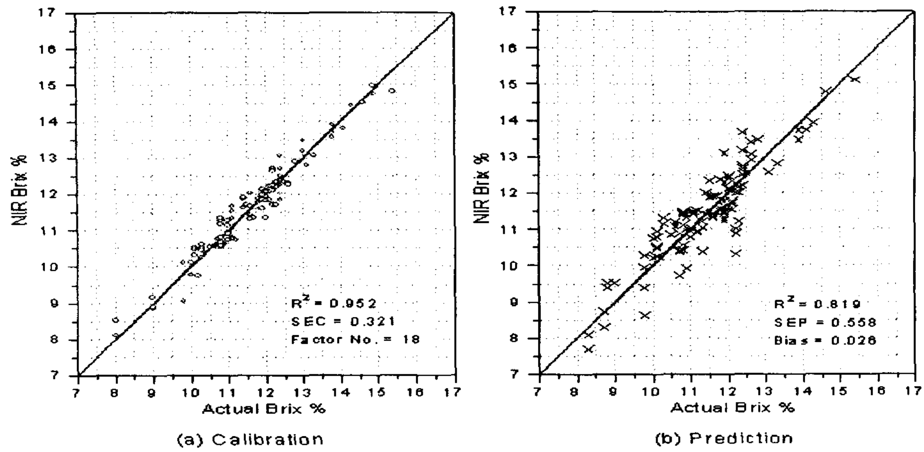

Fig. 8 Plot of actual Brix% of peach vs. Brix% calculated by PLS model(preprocessing : scattering correction=SNV & MSC, 1st derivative, wavelength range : 550 ~ 1000nm)

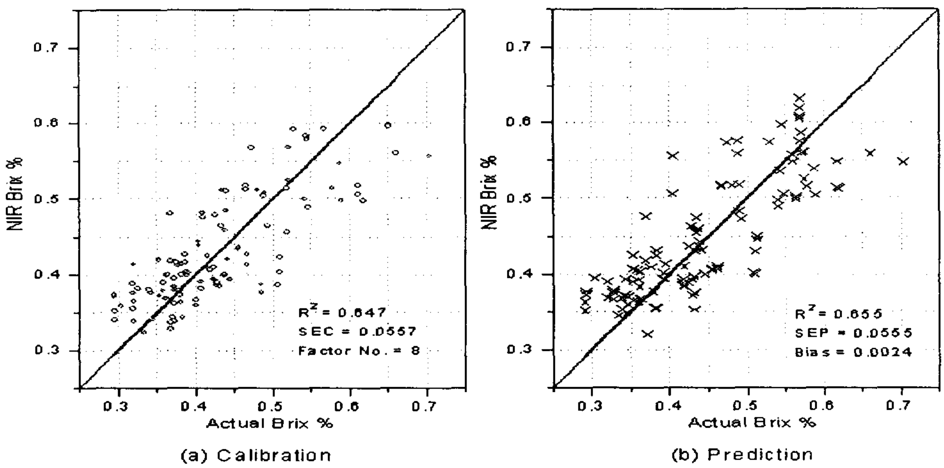

Fig. 9 Plot of actual titratable acidity of peach vs. titratable acidity calculated by PLS model(preprocessing : scattering correction=SNV & MSC, 1st derivative, wavelength range : 550 ~ 1000nm)

CONCLUSIONS

The ultimate purpose of this study was to develop a device to measure the transmittance spectra of intact fruit such as apple, pear, peach, etc. With the transmittance-type NIR device, the feasibility of measurement of the SSC and acid contents in intact fruit cultivated in Korea was tested. The results are summarized as follows;

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