Proceedings of the International Conference for Agricultural Machinery & Process Engineering
October 19-22, 1993, Seoul, Korea

CORRELATION BETWEEN NON-DESTRUCTIVE QUALITY EVALUATION PARAMETERS AND SPECTRAL REFLECTANCE OF PEACHES

Y. H. Kim, C. S. Kim, and C. H. Lee

Department of Agricultural Machinery Engineering
Chonbuk National University
Chonju 560-756, Korea

ABSTRACT

In order to evaluate the quality of peaches non-destructively, the surface color and spectral reflectance of KURAKATAWASE, MIBAEKTO, and OKUBO cultivar were measured. Also an attempt was made to correlate reflectance characteristics with quality evaluation parameters such as chlorophyll, anthocyanin, soluble solid, and firmness.

Key Word : Peach, Quality evaluation, Spectral reflectance, Correlation

INTRODUCTION

In Korea, most of the fruits are classified by sorter based on weight and size. Consumer demand for high-quality fruits requires the development of better sorting techniques to evaluate the quality based on maturity.

Firmness of the flesh, chlorophyll content, and content of soluble solids are the primary internal quality indices of fresh peaches and surface color is the external quality index. Presently, Magness-Taylor Pressure Test is the main method for evaluating the internal quality characteristics of peaches.

However, this test permanently damages the peach and is not applicable when the peach must be examined individually. Surface color, therefore, has been used by many researchers for the nondestructive prediction of the internal quality of fruits.

Bittner and Norris (1968) suggested a quality index which is expressed as the reflectance ratio of 580 nm to 620 nm for red varieties of apples and peaches. Sidwell et al. (1961) reported a transmittance peak at 545 nm for fresh Elberta peaches. But color difference of different varieties is likely to cause a wavelength difference of peak transmittance, which need not especially be related to the stage of maturity. Norris (1958) suggested criteria for judging peach maturity based on a transmittance ratio of 700 and 740 nm of skin color and two reflectance ratios in the 550 to 590 nm wavelength region and another in the 600 to 640 nm region (Bittner and Norris, 1968).

Long and Webb (1973) indicated that a measurement of maturity for peaches, based on the ratios of reflectance values obtained from the total surface area, is possible. The reflectance ratio $R_{675/625}$ was chosen as the most appropriate one for establishing such an index since it correlated significantly with firmness. Kawano et al. (1989) measured sugar content in intact peaches by a near infrared system. Slaughter (1992) developed a non-destructive measurement technique using the absorption characteristics of near infrared light to predict the content of soluble solids.

Light reflectance and transmittance characteristics have been used to evaluate quality factors of agricultural products such as maturity (Birth and Norris, 1958; Long and Webb, 1973), chlorophyll content (Sidwell et al., 1962; Watada et al., 1976), water core (Francis et al., 1965; Bramlage and Shipway, 1967), defects (Li et al., 1993), and other characteristics.

Spectral reflectance of apples were first investigated in the visible region by Kim et al. (1992) in Korea. They analyzed the relationship between spectral reflectance characteristics and quality indices such as chlorophyll, anthocyanin, and soluble solids. The surface color of several varieties of apples were expressed quantitatively in xyz chromaticity coordinates by Bae (1992).

The ultimate objective of this study is to quantify the surface color of peaches and thereby give a measure of internal quality. The specific objectives were:

1) to investigate the surface color and spectral reflectance of peaches in visible region,

2) to correlate non-destructive quality evaluation parameters with spectral reflectance of peaches

MATERIALS AND METHODS

Sample preparation

Three cultivars of peaches, KURAKATAWASE, MIBAEKTO, and OKUBO were used for the experiment. These cultivars were grown at Wanju, Chonbuk. Spectral reflectance was measured for 20 samples of MIBAEKTO and OKUBO cultivars, which classified as fully or less matured by human eye immediately after harvesting. For KURAKATAWASE cultivar, spectral reflectance of 10 fully matured samples were measured.

Surface color measurement

The surface color of peaches was measured in Yxy (CIE 1931), Lab (CIE 1976) coordinate using a tristimulus colorimeter (Minolta Chroma Meter, CR-200) standardized under illuminant C with a white standard plate (Y = 93.5, x = 0.3114, y = 0.3190).

The CR-200 had a built-in pulsed xenon arc lamp and an 8 mm aperture reading a small area of the peach, which minimized the possibility of measuring flecks of red blush color. The average of four readings equally spaced around the peach equator was recorded and used for analysis.

Spectral reflectance measurement

Figure 1 shows a photographs for the measurement system to determine the spectral reflectance of peaches from 400 nm to 700 nm in 50 nm intervals. Measurement system consists of the light source, fiber optics, detector, and data acquisition system. Specifications for the instruments used are given in Table 1.

An emitted light from alight source is filtered by a band-pass filter to monochromatic light and conveyed to the surface of peach through one strand of fiber optics with an illumination angle of 0°. Reflected light is detected by the other strand of fiber optics which has viewing aperture of 4 mm at viewing angle of 45°.

Peaches were placed by hand into the viewing area so that reflectance measurement could be taken from the same spot where surface color was measured.

The reflectance of agricultural products is commonly defined as

$$R = \frac{I_r}{I_o} \times 100,$$

where
R = reflectance (%)
I_r = the reflected energy from sample
I_o = the reflected energy from calibration plate.

The white standard plate of CR-200 was used for calibrating the reflectance measurement system.

Measurement of internal quality evaluation parameters

Firmness of flesh was measured with a universal hardness test meter. Total content of chlorophyll was calculated from the measured absorbance at 651 and 664 nm using a high-intensity spectrophotometer (Gilford 260). Also, anthocyanin pigment was analyzed from the absorbance at 535 nm. Refractomater (Atago No.1) was used to measure the soluble solids expressed in Brix.

Data obtained were analyzed to infer possible linkage between internal quality evaluation parameters and spectral reflectance characteristics of peaches. Simple correlation coefficients between quality evaluation parameters and reflectance characteristics were obtained by SAS (Statistical Analysis System) package. And the test of significance for correlation coeffcients was performed.

RESULTS AND DISCUSSION

CIE color coordinates of peaches

Coordinates of the surface color of KURAKATAWASE, MIBAEKTO, and OKUBO peaches were superimposed on chromacity diagram and shown in Figure 2, 3, 4. The axis of abscissa in the chromaticity coordinates denotes the relative magnitude of red color and the axis of ordinates denotes the relative magnitude of green color. The dominant wavelength for the surface color of samples was obtained from the intersecting point of the spectrum locus and straight-line which connecting the equal energy white point (x=0.3333, y=0.3333) on chromacity diagram and the points of color data.

Ranges of dominant wavelength determined from color coordinates were shown in Table 2. Since the lower limit of dominant wavelength ranges from 562 nm to 572 nm, it makes little difference between cultivars of peach. But the upper limits of dominant wavelength are 582 nm for MIBAEKTO cultivar, 600 nm for OKUBO cultivar, and 780 nm for KURAKATAWASE. This difference might appear because of much red color formation in KURAKATAWASE cultivar.

Reflectance characteristics of peaches

Spectral reflectance of the surface of KURAKATAWASE, MIBAEKTO, and OKUBO peaches were shown in Figure 5, 6, and 7. LM1 and LM2 in the figures denote the spectral reflectances for less matured peaches. M1 and M2 mean the spectral reflectances for fully matured peaches. Reflectances for less matured KURAKATAWASE cultivar increase up to 600 nm and decrease a little to 650 nm region as shown in Figure 5. For fully matured peaches, reflectances increase up to 650 nm and has uniform values after the wavelength of 650 nm.

Compared to the peaches with less maturity, fully matured peaches show low reflectance in the wavelengths from 400 nm to 600 nm and high reflectance above the wavelength of 650 nm. This result would be due to the difference of chlorophyll content and the formation of red color on peach surface.

The reflectance for fully matured MIBAEKTO peaches appears 10-35% higher than that less matured peaches in the visible region as shown in Figure 6. This difference is pronounced at the wavelengths of 550 nm to 600 nm region. Thus when the ripeness of MIBAEKTO cultivar is evaluated, it would be effective to compare the reflectances at 550 nm or 600 nm region.

The reflectance of fully matured OKUBO peaches is higher than that of less matured as shown in Figure 7. This was pronounced at wavelengths higher than 600 nm. For fully matured OKUBO cultivar, the reflectance increases up to 600 nm and then gradually decreases to 650 nm. The reflectance of less matured OKUBO cultivar increases up to 550 nm and shows a minimum at the wavelength of 650 nm. This fact is due to the loss of chlorophyll as the fruits mature. This is in accord with previous results found by Norris (1958), Sidwell et al. (1961), and Bittner and Norris (1968).

Correlation between reflectance characteristics and quality indices

Correlation coefficients between spectral reflectance and quality indices of KURAKATAWASE cultivar are shown in Table 3. It shows that reflectance at 700 nm has a high negative correlation coefficient of -0.8275 for chlorophyll content and would be significant at the 1% level. For anthocyanin, correlation coefficient of 0.7437 at 700 nm has a high significance at the 1% level. Besides, correlation coefficients for soluble solids at 700 nm and for firmness at 550 nm are found to be 0.6769 and -0.6705, respectively.

The correlation coefficients of MIBAEKTO cultivar in Table 4 reveal that the reflectance at 650 nm has the highest correlation of 0.8754 for soluble solids, whereas the reflectance at 600 nm has the highest correlation of -0.8623 for firmness. For chlorophyll content, the reflectance at 500 nm has the highest correlation of -0.8270. These correlations have a high significance at the 0.1% level overall.

Table 5 lists the correlation coefficients of OKUBO cultivar. Correlation coefficients for spectral reflectance of anthocyanin, soluble solids, chlorophyll, and hardness are found to be 0.8115 at 700 nm, 0.8112 at 700 nm, -0.7955 at 650 nm, and -0.7170 at 500 nm, respectively.

Next an attempt was made to correlate the reflectance difference or reflectance ratio with quality evaluation parameters of peaches. Correlation coefficients of chlorophyll, anthocyanin, soluble solids, and hardness for reflectance difference of KURAKATAWASE cultivar did not appear higher than correlation coefficients for spectral reflectance. It appeared that $R_{550/500}$ (reflectance ratio of 550 nm to 500 nm) has the highest correlation coefficient of -0.8128 for soluble solids, whereas $R_{700/550}$ has the highest correlation coefficient of 0.7794 for hardness. The correlation coefficient between reflectance ratio and chlorophyll or anthocyanin content is not statistically significant.

For the correlation coefficients between quality indices and reflectance difference or reflectance ratio of MIBAEKTO cultivar, one observes the following. $R_{600-500}$ (reflectance difference of 600nm and 500nm) has the highest correlation coefficient of -0.8959 for hardness, whereas $R_{700-600}$ has the highest correlation coefficient of -0.7650 for anthocyanin content. Thus, a significance level within 0.1% is applied for both. And $R_{700/600}$ shows a high negative correlation coefficient of -0.7651 for anthocyanin content.

For OKUBO cultivar, it is shown that $R_{600-550}$ has the highest correlation coefficient of 0.8528 for anthocyanin, whereas $R_{700-500}$ has the highest correlation coefficient of 0.8399 for soluble solids.

CONCLUSIONS

For non-destructive evaluation of the quality of peaches, the surface color and spectral reflectance of KURAKATAWASE, MIBAEKTO, and OKUBO cultivar were measured. Also an attempt was made to correlate reflectance characteristics with quality evaluation parameters such as chlorophyll, anthocyanin, soluble solid, and firmness. The results obtained in the present study are summarized as follows.

1. Ranges of dominant wavelength of peaches are found to be 572-780 nm for KURAKATAWASE, 565-582 nm for MIBAEKTO, and 565-600nm for OKUBO. The upper limit for OKUBO cultivar was higher than for MIBAEKTO and OKUBO cultivar. This feature appeared because of much red color formation in KURAKATAWASE cultivar.

2. Correlation coefficient between reflectance and chlorophyll content obtained high negative value of -0.8275 at 700 nm region. Reflectance at 650 nm has the highest correlation of 0.8754 for soluble solids of MIBAEKTO cultivar, whereas reflectance at 600 nm has -0.8623 for hardness and at 500 nm has -0.8270 for chlorophyll content. Correlation coefficients between spectral reflectance and anthocyanin, chlorophyll, soluble solids, and hardness of OKUBO cultivar are found to be 0.8115 at 700 nm, 0.8112 at 700 nm, -0.7955 at 650 nm, and -0.7170 at 500 nm, respectively.

3. $R_{600-500}$ has the highest correlation coefficient of -0.8959 for hardness of MIBAEKTO cultivar, whereas $R_{600-550}$ has the highest correlation coefficient of 0.8528 for anthocyanin content of OKUBO cultivar. For soluble solids, $R_{700-500}$ has the highest correlation coefficient of 0.8399 of OKUBO cultivar.

4. $R_{700/600}$ has the highest correlation coefficient of 0.8623 for hardness of MIBAEKTO cultivar, whereas $R_{550/500}$ has the high negative correlation of -0.8128 for soluble solids of KURAKATAWASE cultivar.

REFERENCES

1. Bae, Y. H. 1992. Color sorting of apples by surface reflectance. J. of the Korean Society for Agricultural Machinery 17(4):382-395.

2. Birth, G. S. and K. H. Norris. 1958. An instrument using light transmittance for nondestructive measurement of fruit maturity. Food Technology 12(11):592-595.

3. Bittner, D. R. and K. H. Norris. 1968. Optical properties of selected fruits vs maturity. Trans. of the ASAE 11(4):534-536.

4. Bramlage, W. J. and M. R. Shipway. 1967. Loss of water core and development of internal breakdown during storage of 'Delicious' apples, as determined by repeated light transmittance measurements of intact apples. Amer. Soc. Hort. Sci. 90:475-483.

5. Francis, F. J., W. J. Bramlage, and W. J. Lord. 1965. Detection of water core and internal breakdown in delicious apples by light transmittance. Amer. Soc. Hort. Sci. 87:78-84.

6. Kawano, S., H. Watanabe, and M. Iwamoto. 1989. Measurement of sugar contents in intact peaches by NIRS. Proc. of the 2nd International NIRS Conference, Tsukuba, Japan.

7. Kim, Y. H., C. S. Kim, S. B. Kim, M. S. Kim, and K. C. Shin. 1992. Correlation between non-destructive quality evaluation parameters and spectral reflectance of apple. J.of the Korean Society for Agricultural Machinery 17(4):370-381.

8. Li, X., T. Iwao, T. Fujimura, S. Shibusawa, and K. Mohri. 1993. Damaged fruits inspecting system by machine vision - Spectral reflectance of peach defects. J. of the Japanese Society for Agricultural Machinery 55(4):91-98.

9. Long, J. F. and B. K. Webb. 1973. Correlations of reflectance ratios to maturity for whole peaches. Trans. of the ASAE 16(4):922-925.

10. Norris, K. H. 1958. Measuring light transmittance properties of agricultural commodities. Agricultural Engineering 39(10):640-643, 651.

11. Sidwell, A. P., G. S. Birth, J. V. Ernest, and C. Golumbic. 1961. The use of light transmittance techniques to estimate the chlorophyll content and stage of maturation of Elberta peaches. Food Technology 19(3):75-78.

12. Slaughter, D. C. 1992. Near infrared analysis of soluble solids in peaches. ASAE Paper No.92-7056.

13. Watada, A. E., K. H. Norris, J. T. Worthington, and D. R. Massie. 1976. Estimation of chlorophyll and carotenoid contents of whole tomato by light absorbance technique. J. Food Sci. 41:329-332.

Table 1. Specifications for instruments used in the experiment.

Item	Specifications
Light Source	Halogan Lamp 300W/120V
Band pass filter	400nm to 700nm
Fiber optic	Bundle
Photomultiplier tube	Head-on type 2" diameter (R669)
High-voltage power supply	±3000V dc
Magnetic shield case	2" diameter

Table 2. Range of dominant wavelength of the surface color of the peaches obtained from the chromaticity coordinates.

Cultivar	Range of dominant wavelength
KURAKARAWASE	572 nm - 780 nm
MIBAEKTO	565 nm - 582 nm
OKUBO	565 nm - 600 nm

Table 3. Correlation coefficients between reflectance and quality indices for 'KURAKATAWASE' cultivar of peaches.

Indices	Wavelength				
	500nm	550nm	600nm	650nm	700nm
Chlorophyll	0.0030	0.1856	0.0143	-0.3586	-0.8275**
Anthocyanin	-0.1846	-0.2768	-0.0252	0.6435*	0.7437**
Soluble solids	-0.0903	-0.3927	-0.1134	0.6274	0.6769*
Firmness	-0.6569*	-0.6705*	-0.6094	0.0895	0.2052

* means significance level at the 5%

** means significance level at the 1%

Table 4. Correlation coefficients between quality indices and reflectance for 'MIBAEKTO' cultivar of peaches.

Indices	Wavelength				
	500nm	550nm	600nm	650nm	700nm
Chlorophyll	-0.8270***	-0.7912***	-0.7989***	-0.7723***	-0.7557***
Anthocyanin	0.5517	-0.6816***	0.6780**	0.5200	-0.6093**
Soluble solids	0.8306***	-0.8061***	-0.7995***	0.8754***	0.8246***
Firmness	-0.7490***	-0.7654***	-0.8623***	-0.7425***	-0.7078***

* means significance level at the 5%
** means significance level at the 1%
*** means significance level at the 0.1%

Table 5. Correlation coefficients between quality indices and reflectance for 'OKUBO' cultivar of peaches.

Indices	Wavelength				
	500nm	550nm	600nm	650nm	700nm
Chlorophyll	-0.5458*	-0.2808	-0.7920***	-0.7955***	-0.7643***
Anthocyanin	0.3212	-0.0846	0.7503***	0.7871***	-0.8115**
Soluble solids	0.3365	-0.0341	0.7213***	0.7987***	0.8112***
Firmness	-0.7170***	-0.6655**	-0.5795**	-0.5119*	-0.4682*

* means significance level at the 5%
** means significance level at the 1%
*** means significance level at the 0.1%

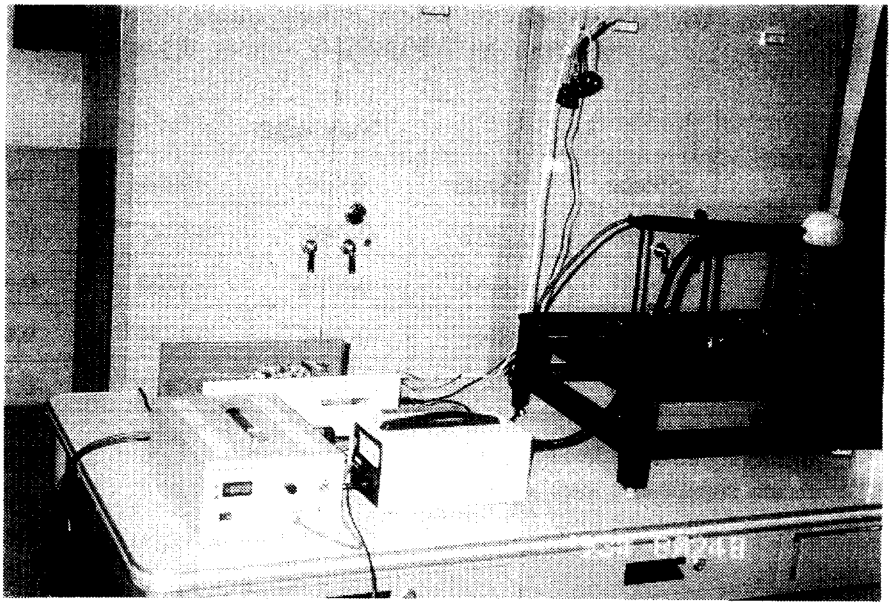

Fig. 1. Photographs of measurement system to determine the spectral reflectance of peaches.

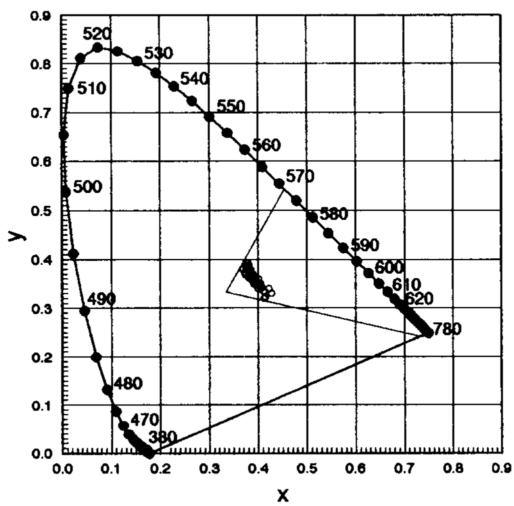

Fig. 2. Chromaticity coordiantes of the surface color of 'KURAKATAWASE' peaches.

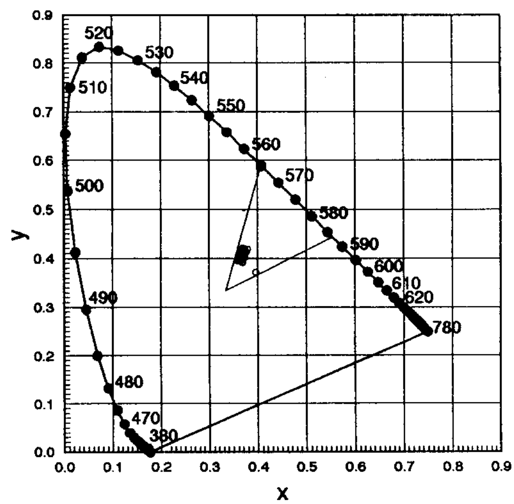

Fig. 3. Chromaticity coordiantes of the surface color of 'MIBAEKTO' peaches.

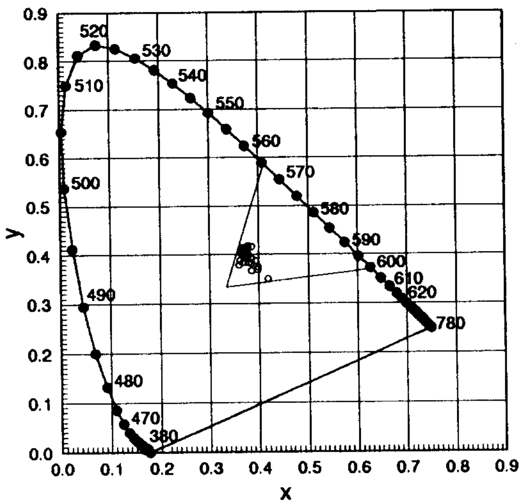

Fig. 4. Chromaticity coordiantes of the surface color of 'OKUBO' peaches.

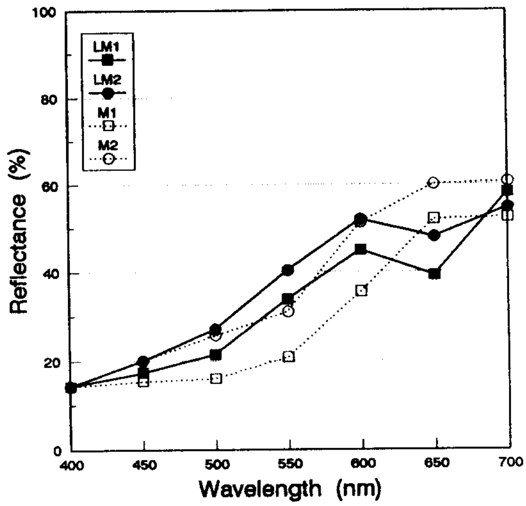

Fig. 5. Reflectance curves for 'KURAKATAWASE' cultivar of peaches.

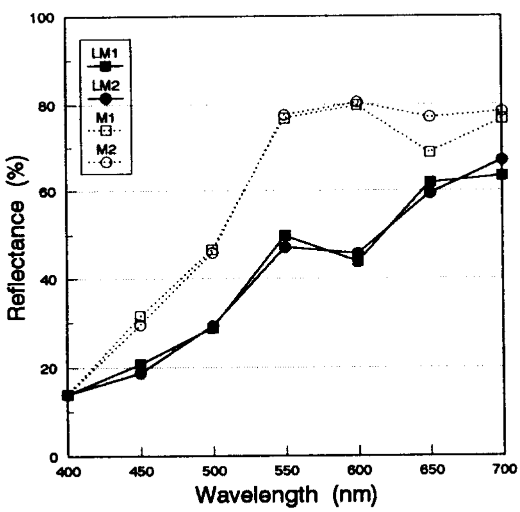

Fig. 6. Reflectance curves for 'MIBAEKTO' cultivar of peaches

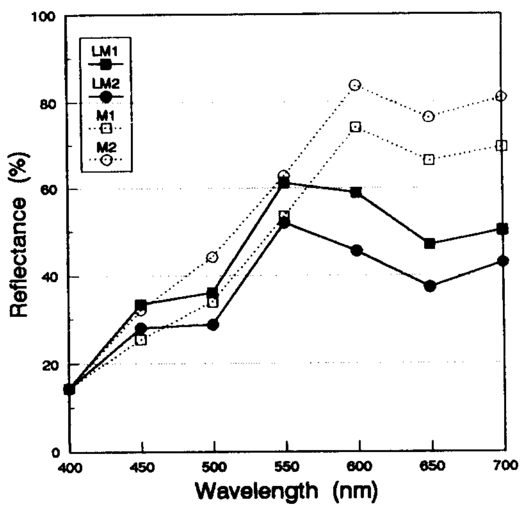

Fig. 7. Reflectance curves for 'OKUBO' cultivar of peaches.