Application of Light Reflectance Properties of Satsuma Oranges to Automatic Grading in the Packinghouse Line : Relationship between Grading Index and Spectral Reflectance

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https://doi.org/10.5109/23738

J. Fac. Agr., Kyushu Univ., 26(1), 45-55 (1981)

Application of Light Reflectance Properties of Satsuma Oranges to Automatic Grading in the Packinghouse Line

Relationship between Grading Index and Spectral Reflectance

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(Received July I, 1981)

A single wavelength reflectance method at 680nm. the chlorophyll absorption band, was used as a means of separating Satsuma oranges in the packinghouse line according to their ripeness and internal quality (sugar and acid content). As the correlation between this grading index and the color index evaluated by human judgement was high, this measurement method was found to be useful for color index evaluation. As spectral reflectance decreases with the lapse of time after picking, the fruits should be graded as soon as possible.

INTRODUCTION

Although packinghouses are becoming larger and more automated, the grading process still requires many trained laborers. Psychological factors surrounding the involvement of human beings in the grading process lead to the introduction of errors and reduced efficiency. For example, workers become tired which, in turn, diminishes their capacity and increases their chance for making errors. Psychological troubles may divert their attention from the task of grading, thus compounding the errors.

Manual grading of many fruits involves the judgement of the color of the blossom and stem ends. The surface color of the Satsuma oranges has been found to be related to chlorophyll content, acidity, and total sugar content of the flesh (Shiraishi, 1972; Suzuki *et al.,* 1974).

There have been many attempts to develop nondestructive sorting techniques which offer improvements over manual methods (Bittner and Norris, 1968; Heron and Zacharish, 1974; Long and Webb, 1973; Powers et al., 1953). Properties of light transmittance (Chuma *et al.,* 1974) and delayed-light-emission (Chuma *et al.,* 1977) are two recent examples. These methods appear to require complex optical arrangements. This paper reports the development of a sorting method, based on light reflectance, which would be relatively simple compared to previous methods yet effective in its application.

MATERIALS AND METHODS

1. Material

Satsuma oranges (Miyagawa) harvested during the 1976–77 season were used in this experiment. Just after harvest the oranges were visually selected to be approximately the same size but of different color. Measurement of the reflectance properties was carried out immediately following the visual selection process.

2. Measuring of light reflectance properties

A. Measuring apparatus

The basic features of the experimental apparatus (Chuma *et al.*, 1976) are illustrated in Fig. 1. The light source consists of a tungsten-halogen lamp which provides extra energy at short wavelengths compared to ordinary tungsten lamps. The viewing area of the fruits was kept constant by the use of a sample port making remaining size differences less effective.

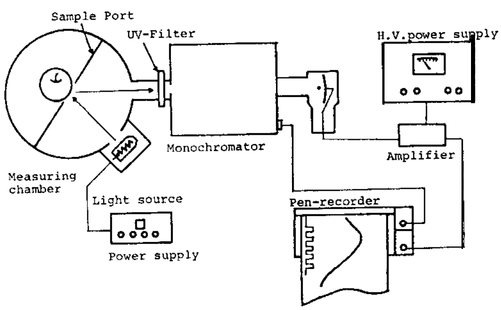

Fig. 1. Schematic diagram of the experimental apparatus.

Light from the lamp illuminates the fruits through the sample port and the reflected light from fruits passes through a UV-filter to a Nikon P-250 monochromator. The reflectance properties were recorded over the 400 to 800 nm regions with a multiplier-type phototube with an S-4 response.

B. Measuring method

The spectral intensity of a painted white glass ball (the standard) was measured before and after the spectral intensity of the fruits was measured. The glass ball was approximately the same size as samples. The effect of stray light reflected from the black felt walls of the chamber was less than 3 % of the total specular intensity. The spectral reflectance of each fruit was computed as the ratio of the spectral intensity of the sample to the spectral intensity of the white glass standard.

3. Analyzing chlorophyll content

The chlorophyll content of the area of the peel from which the reflectance measurement was made was determined by a spectrophotometric technique preceded by a methyl alcohol extract procedure (Mackinney, 1941). The chlorophyll content (CC) was calculated from the following formula:

$$CC = (25.5\,A_{650} + 4.0\,A_{665}) \times V/20$$

where

CC=ratio of chlorophyll content in mg to the weight of the peel in 100 gr,
A_{650} = absorbance of the extract at 650 nm,
A_{665} = absorbance of the extract at 665 nm,
V = volume of methyl alcohol extract in ml.

4. Analyzing total sugar and acidity

Total sugar content was measured by a hand refractometer in Brix. Acidity was obtained by determining the weight in grams of sodium hydroxide required to neutralize the citric acid in 100 ml of fruit juice.

RESULTS AND DISCUSSION

1. Effect of illuminance

Effect of illumination on the intensity of reflected light at 680 nm is shown

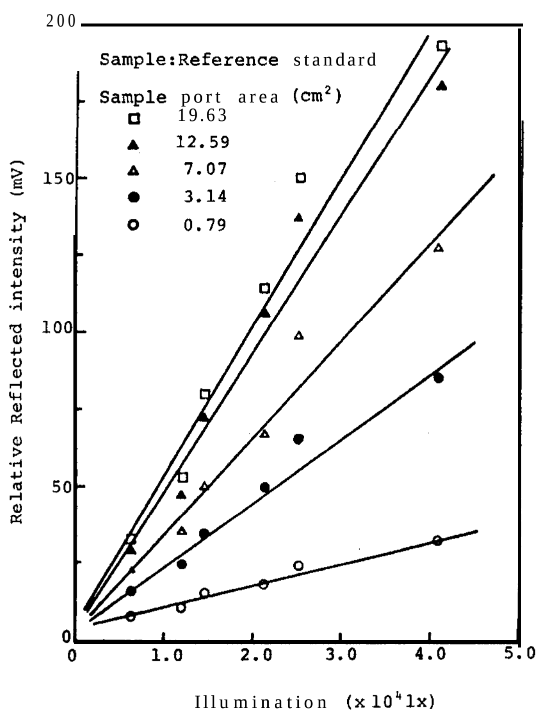

Fig. 2. Effect of illumination on the intensity of reflected light from the white glass standard at 680nm.

in Fig. 2. A 72mm diameter glass ball was used as the sample for all port sizes shown. Incident illumination was adjusted by regulating the voltage at the light source. For each port size, the intensity of the reflected light incresed linearly with increasing illumination. It was assumed that this linear relationship hold over the various port sizes so that further tests were conducted with an illumination of 4.07 x 10^4 lx.

2. **Effect of sample port area**

Fig. 3 shows the effect of the sample port area on the relative reflected intensity at 680nm. All data shown were taken on the 72mm diameter glass standard. For fixed illumination the relative reflected intensity increased nonlinearly with port size. The nonlinearity was attributed to the sample curvature. The port size of 19.6 cm^2 (50 mm diameter) was chosen for further tests.

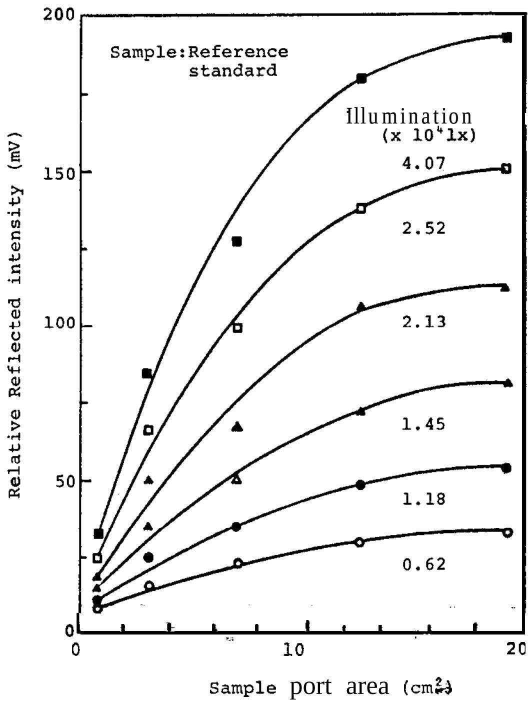

Fig. 3. Effect of sample port area on the intensity of reflected light from the white glass standard at 680 nm.

3. **Effect of sample size**

Sample size for a given port area, had little effect on the relative reflected intensity at 680nm (see Fig. 4). This optical arrangement appears to almost remove sample size effects which were observed in other experiments and seems to obviate the need for dual wavelength measurements which are

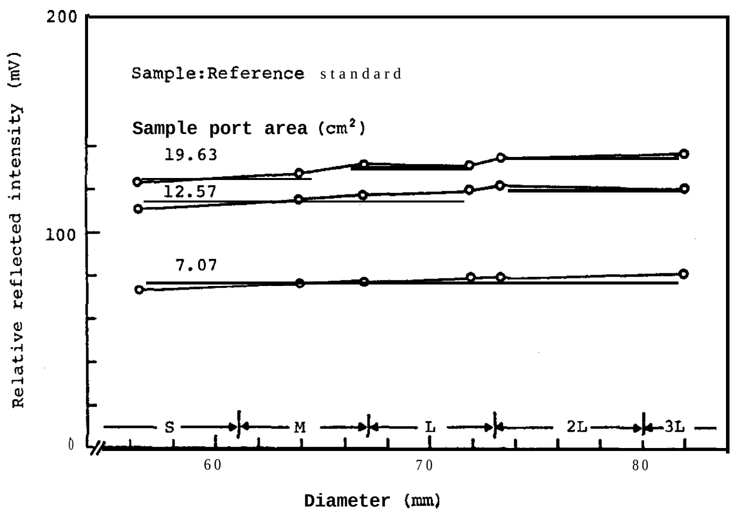

Fig. 4. Effect of sample size on the intensity of reflected light at 680 nm.

usually proposed as a method for minimizing size effects.

4. **Relationship of the chlorophyll content of the peel to spectral reflectance**

Spectral reflectance curves of the blossom and stem ends of different colored Satsuma oranges are shown in Fig. 5. The most outstanding charac-

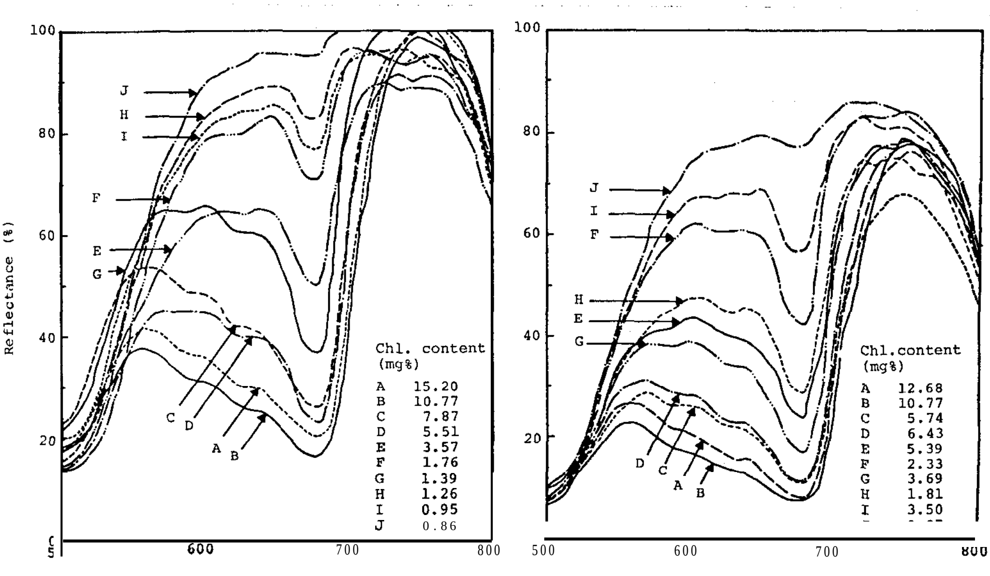

Fig. 5. Spectral reflectance curves for different colors of Satsuma oranges (left: blossom end, right: stem end).

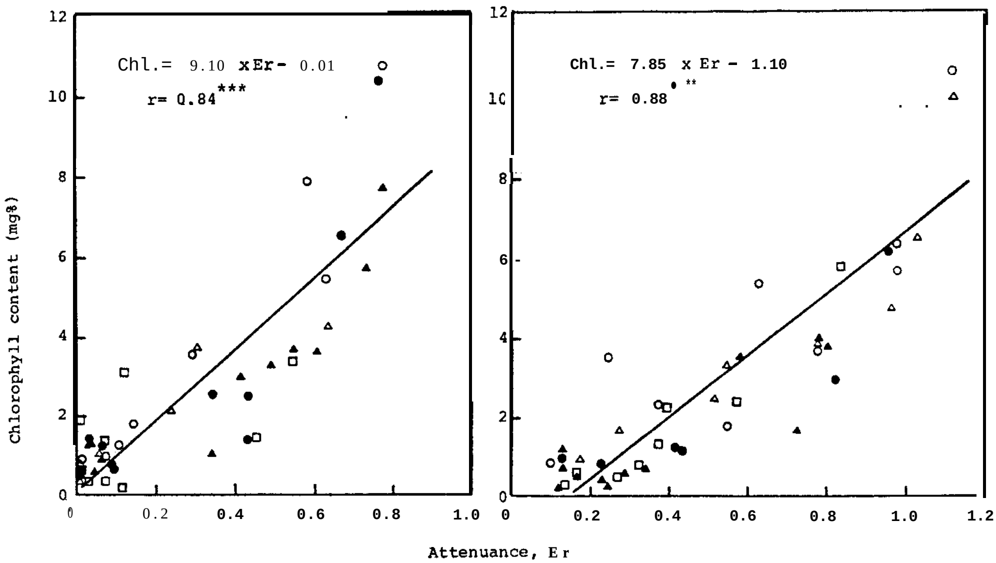

Fig. 6. Relation between attenuance at 680nm and chlorophyll content of Satsuma oranges (left: blossom end, right: stem end).

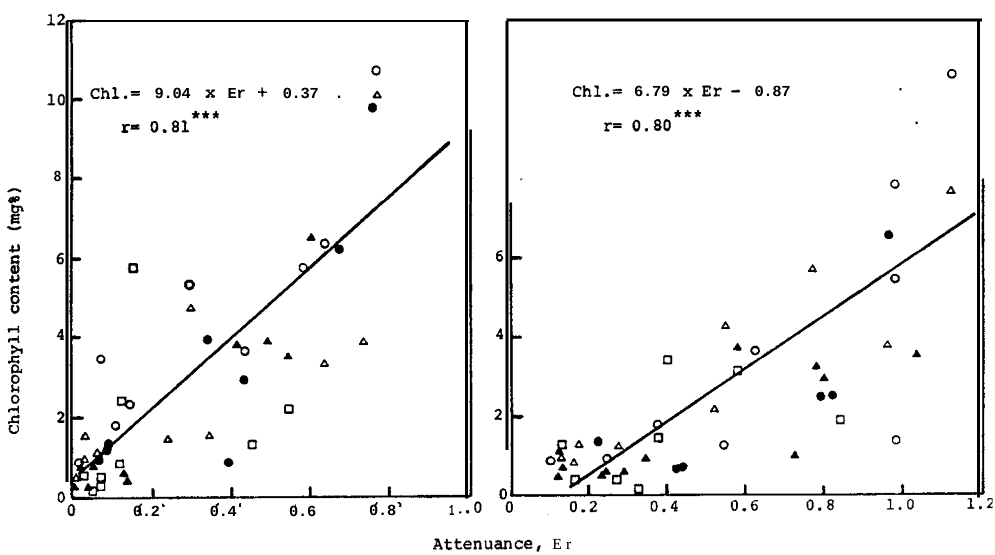

Fig. 7. Relation between attenuance at 680nm and chlorophyll content of Satsuma oranges (left: attenuance at the blossom end and chlorophyll content at the stem end, right: attenuance at the stem end and chlorophyll content at the blossom end).

teristic of the two sets of curves is the chlorophyll absorption band at approximately 680nm. It was also noted that the stem end had a lower reflectance than the blossom end. This was attributed to the stem scar which is more 'woody" and has less reflectance than other portions of the peel.

The dependence of attenuance (log l/R 680) on chlorophyll content is shown in Fig. 6. The relationship between attenuances and chlorophyll content is linear and correlated at the both ends of each fruit.

The problem of estimating the color (i.e., chlorophyll content) of whole fruit from spot illumination was investigated by determining the relationship of chlorophyll content of the stem end to the attenuance of the blossom end and vice *versa.* Fig. 7 shows that the chlorophyll content of either the stem end or the blossom end can be calculated from measurements on the opposite end. Thus, it seems probable that the chlorophyll content of the whole fruit could be estimated from a single measurement on part of the peel.

5. **Attenuance vs. color index**

Fig. 8 shows the relationship between attenuance and the color index of Satsuma oranges. The color index was established by visual observation of the stem end of each fruit. Then the relationship between the color index for the stem end and the measurements of attenuance for the both ends were obtained.

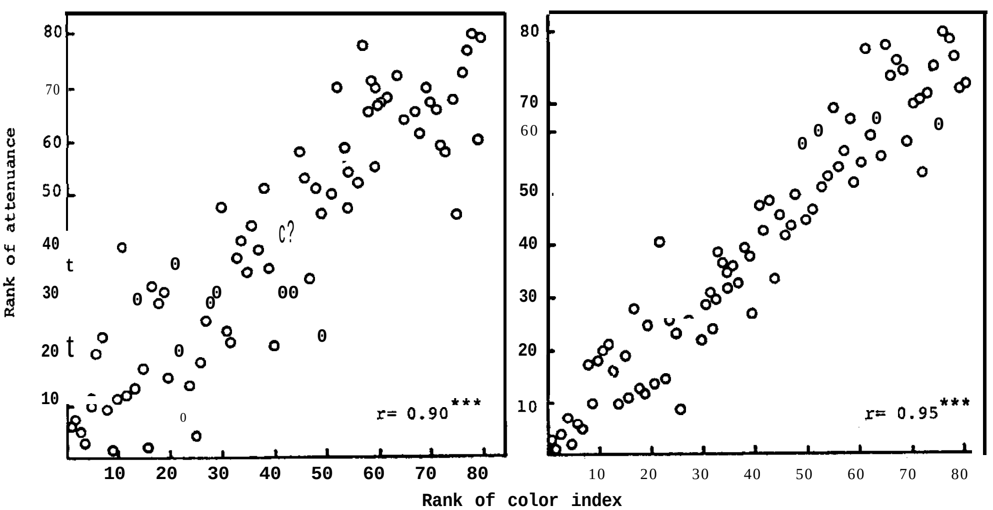

Fig. 8. Correlation diagram between the ranks of attenuance at 680 nm and color index of Satsuma oranges (left: attenuance of the blossom end and color index, right: attenuance of the stem end and color index).

Spearman's rank correlations (Snedecor and Cochran, 1972) of the color index with attenuance for the both ends were determined on two sets of samples as follows:

Set no.	Stem end	Blossom end
1	0.95***	0.90***
2	0.94***	0.78***

*** Significant at 0.1% level.

6. **Attenuance vs. internal quality**

Earlier research showed that chlorophyll content of peel was related to total sugar content and acidity of flesh. Fig. 9 shows the relationship attenuance to sugar content of Satsuma oranges. Note that sugar content decreases as attenuance increases which also implies that sugar content increases as chlorophyll content decreases.

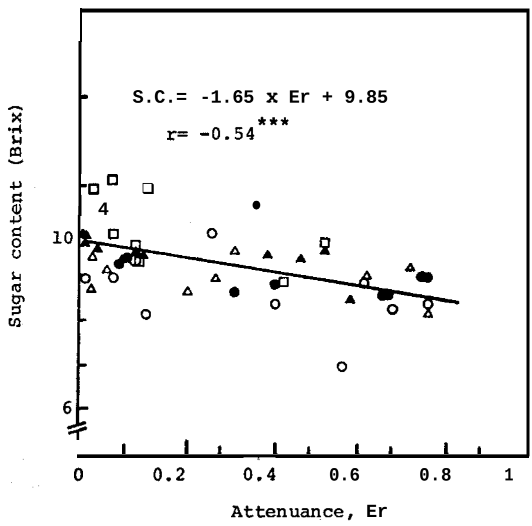

Fig. 9. Relation between attenuance at 680nm of the blossom end and sugar content of Satsuma oranges.

Acidity of Satsuma oranges increases with an increase in attenuance (see Fig. 10). This also implies that acidity increases with chlorophyll content.

The correlation between attenuance and internal quality was not as high as that between attenuance and color. However, it should be remembered that the former relationship (attenuance vs. internal quality) is an indirect one; that is, attenuance at 680 nm measures chlorophyll and chlorophyll is related to internal quality.

Suzuki et *al.* ***(1975)*** investigated the relationship between ΔOD (optical density) and internal quality of oranges. They reported that total sugar content could be estimated by ΔOD (675–740), and specific gravity and weight of fruit and citric acid content could be estimated by ΔOD (690-740). They also

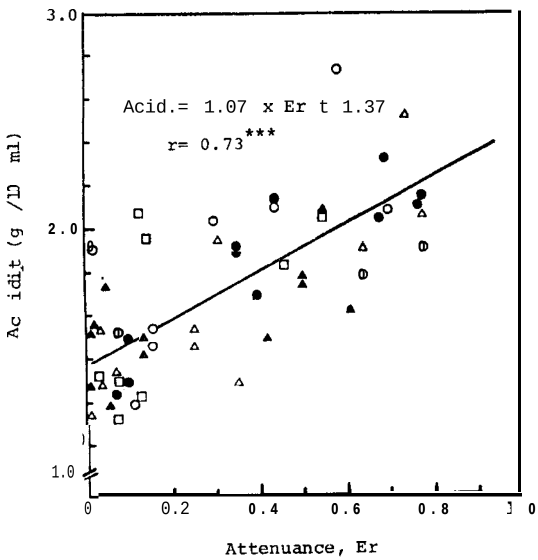

Fig. 10. Relation between attenuance at 680nm of the blossom end and acidity of Satsuma oranges.

showed that chlorophyll content was more highly correlated to sugar content than to citric acid content. However, they too found low correlation between internal quality and the ΔOD measurements.

7. **Changes of spectral reflectance**

Fig. 11 shows the change of the spectral reflectance of Satsuma oranges

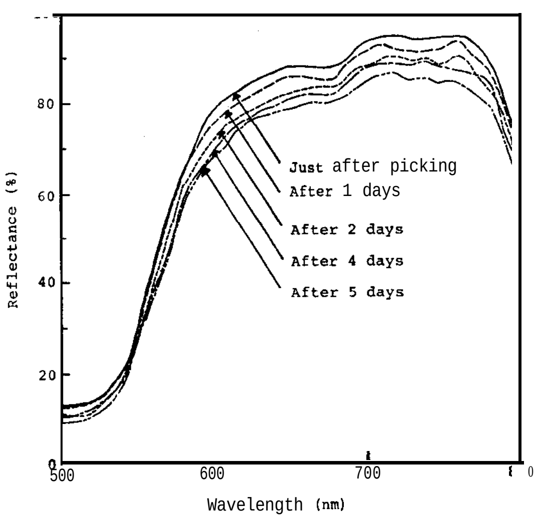

Fig. 11. Change of spectral reflectance of Satsuma orange after picking.

for up to 5 days after harvesting. The changes were characterized as a down shift of the spectra. This can probably be attributed to surface changes caused by moisture loss, etc. Though the shift appears to be small, the change represents a 7 % change at 680 nm, a change which cannot be neglected and which implies sorting should be accomplished very soon after picking.

CONCLUSIONS

The following conclusions were reached :

1. A sample view port of 50mm was found to be optimum.

2. Intensity of reflected was found to be essentially constant for varying fruit sizes.

3. The chlorophyll content of the blossom end and attenuance (log l/R) at 680 nm had a high correlation coefficient of 0.84 and 0.88 at the stem end. Furthermore, correlation between attenuance at the stem end and chlorophyll content at the blossom end was 0.80; correlation between attenuance at the blossom end and the chlorophyll content at the stem end was 0.81. All correlations were significant at the 0.1% level.

4. Color differences between the stem end and the blossom end were not considered to be negligible. Measurements of attenuance at both parts of a fruit would provide better sorting of Satsuma oranges.

5. Chlorophyll content had a high correlation with sugar and acidity content, but the correlation coefficients were not as high as those between attenuance and chlorophyll content and between attenuance and color index.

6. Spectral reflectance of Satsuma oranges decreases significantly within five days after harvesting. Therefore, sorting should be accomplished as soon as possible after picking.

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