〔宮崎大学農学部研究報告 50(1・2)(49−55)(2004)
Bulletin of the Faculty of Agriculture, University of Miyazaki 50(1・2)(49−55)(2004)〕

Color Analysis of Carrots and Lemons by Using Spectrophotometer

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(Accepted on January 26, 2004)

Summary: This research was carried out to assess the distribution of color in carrots, green lemons and yellow lemons for quality estimation. The color measurements of these fruits and vegetable were taken from a coordinate system of points on the surface. A Minolta Spectrophotometer (CM-508i) was used to measure a* and b* in the CIE L*a*b* color model with the standard illuminant (D_{65}) and spectral wave of reflectance in visible range (400-700) nm. For color analysis using the Coefficient of Variation (CV) as an indicator of color homogeneity, carrots and yellow lemons were found to have lower CV values of a* and b* than the green lemons. From the result of CV analysis of the spectral wave of reflectance in visible range, the carrots and yellow lemons only had primary color that a single measurement point of color may be possible. On the other hand, green lemons having a secondary color required more measurement points to accurately describe the color of the fruits.

Key words: CIE L*a*b*, Spectral wavelength, Color distribution, Carrot, Lemon.

Introduction

Visual appearance has been the primary basis of the consumers to assess the value of products in a purchase situation (Jahns et al. 2001). It can be further broken down into visual size, color, presence of pathological defects, shape, and presence of physiological abnormalities. Perhaps aside from information about variety and size of the product, color, its extent of distribution, can distinctively represent its quality state. The colors of fruits and vegetables can primarily indicate their level of ripeness. In some cases, it can also indicate some internal qualities of the fruit.

Some researches measured the color of fruits in one or several points (three to five) around the fruit surface (Kondo et al 2000, Marais et al. 2001, Crisosto et al. 2002, Laykin et al. 2002, Racheli ninio et al. 2003, Batu 2004). However, because some fruits have high variability of color, their measurements may not completely indicate representative color information of the fruit. Blasco and others (2002) discussed that some fruits have one color homogenously distributed on the surface, which can be called a primary or global color. Some other fruits like peaches, apples and tomatoes have a secondary color that can also be used as an indicator of

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ripeness. These kinds of fruits cannot rely solely on the global color alone. So, there is a need to develop a technique to systematically evaluate the color of the fruit for an accurate description of the chromatic information.

The main objective of this study is to assess the distribution of color in carrots, green lemons and yellow lemons. Color analysis of these fruits and vegetable was done using both the CIE $L^*a^*b^*$ color model and the spectral profile in the visible range.

Materials and Methods

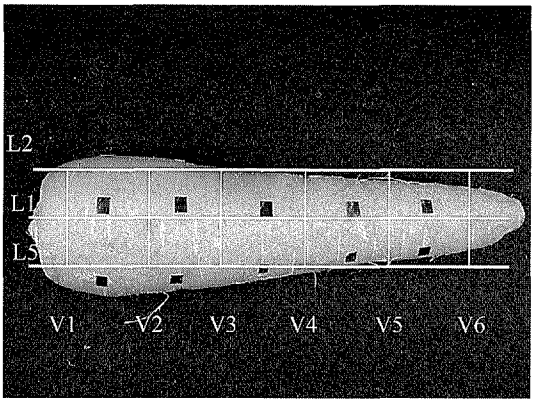
1. Fruits Collection and Preparations

Samples for analysis were four pieces each of carrots (*Daucus carota*) and lemons (*Citrus aurantifolia*), which were obtained from the market. The carrots and yellow lemons represent homogeneously colored fruit and vegetable, while the green lemons represent non-homogeneously colored fruit because they have a secondary color with some yellow portion. To quantify the sizes of the fruits, the lengths and diameters were measured using a vernier caliper.

Some equidistant longitudinal lines (L line) and lateral lines (V line) were drawn on the surface of the fruits to define a coordinate system of points for measurement. As shown in Fig. 1 and Fig. 2. The longitudinal lines were labeled as Line 1, Line 2, and so on. On the other hand, the lateral lines were labeled as top, upper, center, lower and bottom. Fig. 1 shows an example of the coordinate system for carrots, while Fig. 2 shows the same for the lemons. About 30 points were marked on the surface of the carrots and about 18 points on the lemons.

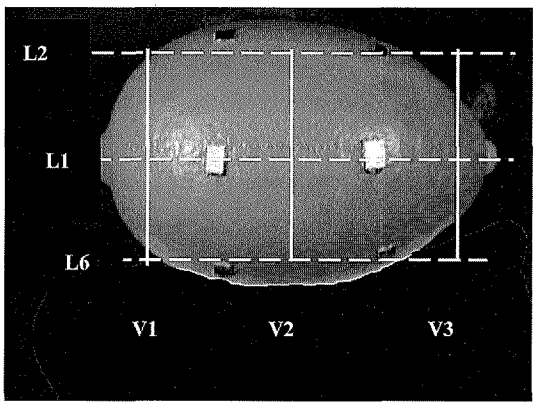
2. Instrument Set-up and Measurement Techniques

The instrument for measuring colorimetric data was constructed in a Minolta Spectrophotometer (CM-508i) with a standard illuminant (D_{65}) and a microcomputer (NEC PC9800). The instrument had an integrating sphere that standardizes the color acquisition settings. Additionally, a reference white tile, was used to calibrate the instrument. Fig. 3 shows the instrument set-up. In the established measurement points around the fruits, CIE $L^*a^*b^*$ values were taken with D_{65} as the reference illuminant and the diffused reflectance spectra were measured from 400 to 700 nm at 10 nm intervals. Each points on the surface of each sample were measured three times as replicates.



L line (total five lines; L1, L2, L3, L4, L5)
V line (total six lines; V1 : Top, V2 : Upper, V3 : Center, V4 : Lower, V5 : Bottom, V6 : End).

Fig. 1. Intial positions, lines and quantity measurement on surface of carrot.



L line (total six lines; L1, L2, L3, L4, L5, L6)
V line (total three lines; V1 : Top, V2 :Center, V3 : Bottom).

Fig. 2. Intial positions, lines and quantity measurement on surface of Lemon.

1. Spectrophotometer Minolta (CM-508i Series)
2. Computer (NEC-PC9800)

Fig. 3. Instruments for experiment.

3. Statistical Data Analysis

Average value (x) from three replicates at each point on each sample were computed. And number of x were 30 data for carrots and 18 data for lemons. Furthermore, average value (X) and standard deviation (σ) were computed from x by using Microsoft Excell for each sample.

To compare the distribution of color on the surface of each sample, the coefficient of variation (CV) was used. The formula for CV is as follows :

$$CV = \frac{\sigma}{X} \times 100\,(\%)$$

By using above mentioned of x, X, σ and CV, a* and b* of CIE L*a*b* and spectral wave of reflectance in visible range were calculated.

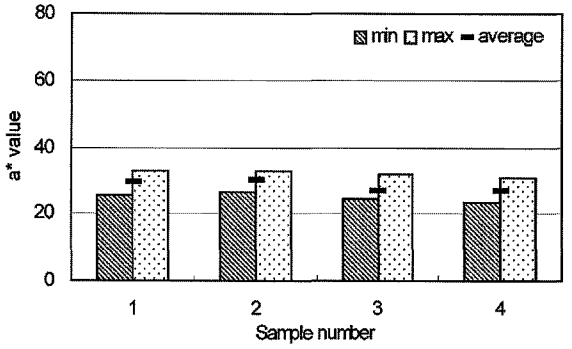
Result and Discussion

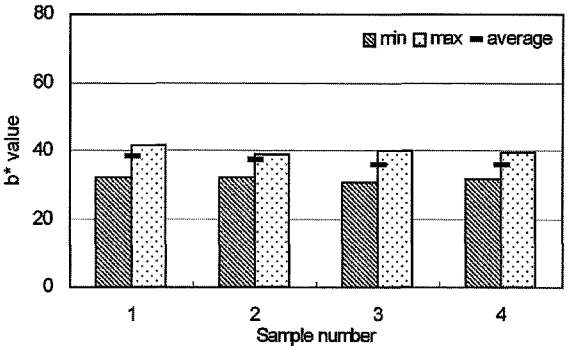
Figure 4 shows the a* and b* values of the different samples of carrots, green and yellow lemons. Carrots being dominantly orange in color had high values for red and yellow. On the other hand, the green lemons had negative values for a* (green is the complimentary color of red in the a* axis) with high values of yellow. The yellow lemons had low values of a* around zero, and extremely high values of b* that explained the dominance of the yellow pigment in the fruit.

From Table 1, the values of the coefficient of variation (CV) can be seen for the different fruits and vegetable. Carrots had relatively low values of CV that indicates a single global or primary color. Moreover, the yellow lemons had high CV values for a*. However, because of extremely low values of this color (around zero), the analysis may be focused more on the b* information. Incidentally, the low CV values for b* indicates a relatively homogenous color for this fruit. On the other hand, the green lemons had relatively high values either for a* or b* that indicates the presence of a secondary color. Therefore, the green lemons have a more varied color distribution that can easily be seen from visual inspection.

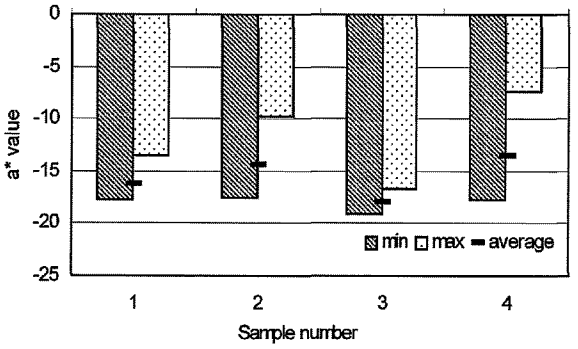
The spectral profiles of the samples are shown in Fig. 5. From these graphs, lesser variation in profiles can be observed from carrots and yellow lemons. This means that the fruits were quite homogeneously colored. On the other hand, larger variations can be observed from the green lemons, which indicate large differences in colors from one fruit to another. Table 2 summarizes the average reflectance values of the different samples. Smaller CV values can be observed from the carrots and yellow lemons and extremely high values for green lemons. This confirms the earlier analysis for non-homogenous distribution of colors for the green lemons. From these analysis, a single color measurement can be done for fruits having a relatively homogenous color. Such single measurement can completely represent the level of color quality of the fruits such as carrots and yellow lemons. However, for fruits having a secondary color such as tomatoes, green lemons, mangoes and papayas, color measurement must be done throughout the surface of the fruit to accurately and correctly describe the level of color quality of the fruit.

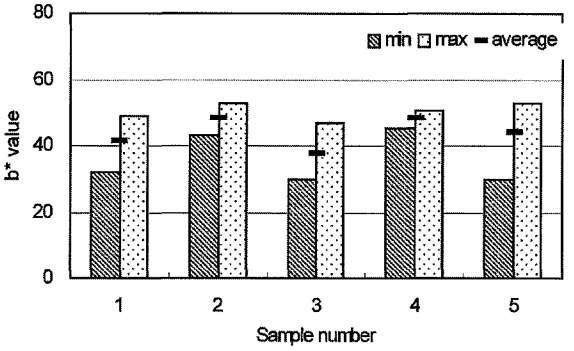
a. Carrot



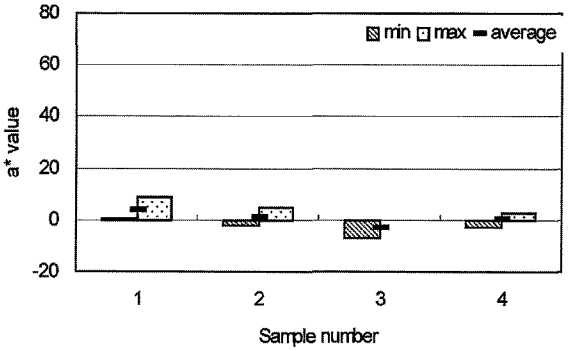


b. Green Lemon





c. Yellow Lemon



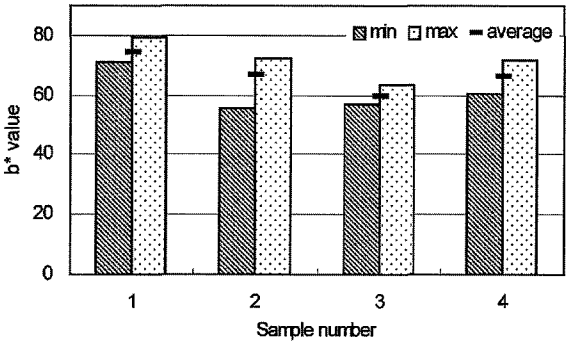
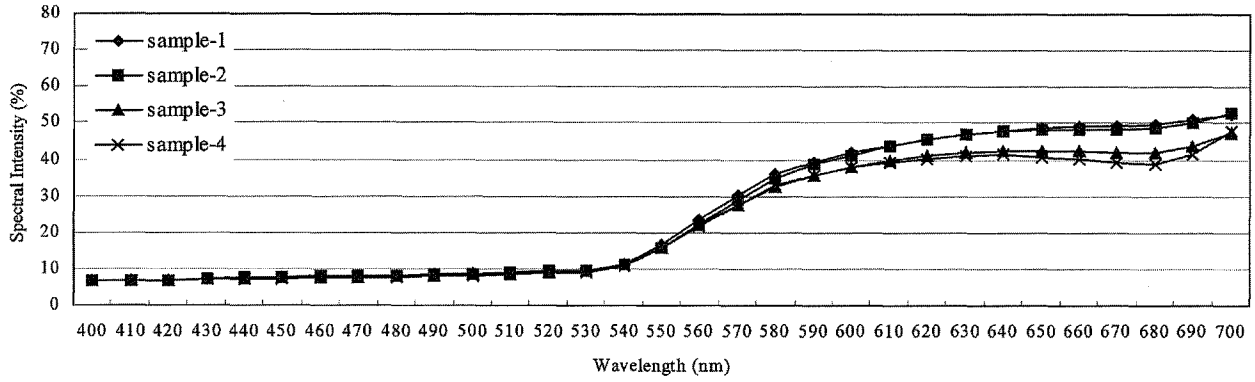
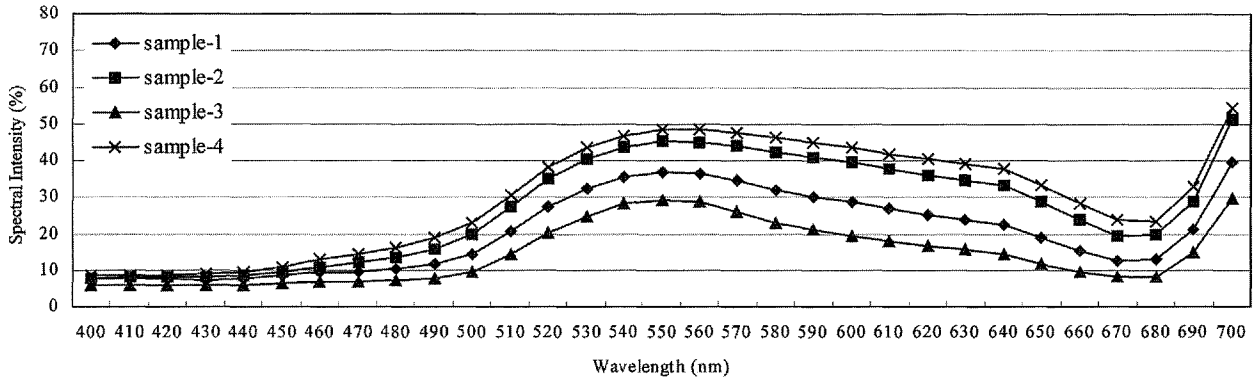


Fig. 4. a* and b* values of carrot, green lemon and yellow lemon.

a. Carrot



b. Green Lemon



c. Yellow Lemon

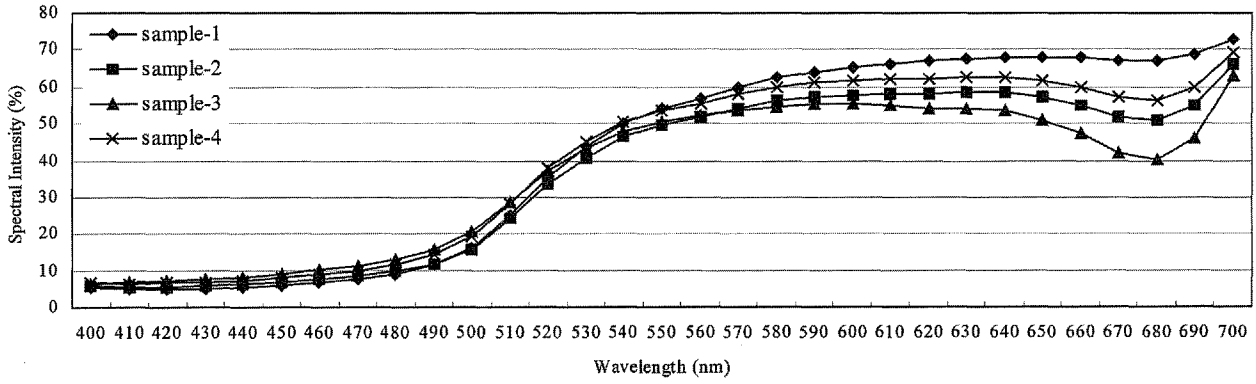


Fig. 5. Spectral graph of carrot, green lemon and yellow lemon.

Table 1. Average, standard deviation and coefficient of variation of a* and b* for each samples.

Fruit and vegetables	Sample no.	a*			b*		
		Average (X)	Standard deviation (σ)	Coefficient of variation (CV) (%)	Average (X)	Standard deviation (σ)	Coefficient of variation (CV) (%)
Carrot	1	29.79	1.93	6.489	38.54	2.25	5.850
	2	29.97	1.86	6.217	37.36	1.84	4.926
	3	27.00	1.77	6.571	35.69	2.25	6.305
	4	26.76	1.75	6.527	35.77	2.06	5.753
Green lemon	1	−16.30	1.24	7.590	41.535	6.201	14.929
	2	−14.44	2.56	17.704	48.330	2.422	5.011
	3	−17.98	0.69	3.825	37.965	5.281	13.909
	4	−13.55	2.93	21.655	48.378	1.290	2.667
Yellow lemon	1	4.067	2.751	67.649	74.709	2.105	2.817
	2	1.513	1.954	129.150	67.105	3.679	5.483
	3	−3.132	1.839	58.725	59.608	1.724	2.892
	4	0.374	1.488	398.416	66.184	2.841	4.292

Table 2. Standard deviation and coefficient of variation from spectral wave of reflectance for each samples.

Fruit and vegetables	Sample no.	Standard deviation (σ)	Coefficient of variation (CV) (%)
Carrot	1	1.776	7.553
	2	1.637	9.169
	3	1.252	6.421
	4	1.437	7.476
Green lemon	1	6.07	29.30
	2	6.44	24.13
	3	3.27	20.03
	4	7.68	26.46
Yellow lemon	1	1.832	7.144
	2	2.543	8.823
	3	4.480	13.098
	4	2.765	7.378

Conclusion

1. Carrots and yellow lemons had more uniform distribution of color in their surface and had only primary color information.
2. Green lemons, while having a secondary color, had non-homogenous distribution of colors. Therefore, a correct measurement of color of such fruits must be done throughout the surface.
3. The spectral profiles obtained better analysis of uniform color distribution for fruits and vegetables.

Acknowledgement

The authors would like to express sincere gratitude to fourth grade students for their kind assistance in doing the research.

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スペクトロホトメータによるニンジンとレモンの着色度分析

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要 約

本研究は，ニンジン，グリーンレモンおよびイエローレモンの品質評価として着色分布について検討を行なったものである．これらの果実の色分布を測定するために果実表層に測定ポイントを設定した．本実験は，標準光D_{65}を持ったスペクトロホトメータ（ミノルタCM-508i）を用いてCIE $L^*a^*b^*$表色系のa^*とb^*の測定ならびに可視光領域（400-700 nm）の分光反射強度の測定を行なった．同一色の判定レベルとして変動係数（CV）を用いて分析した結果，ニンジンとイエローレモンはグリーンレモンよりCV値が低かった．また，分光反射強度のCV値から，ニンジンとイエローレモンは極めて同一な着色分布であることから，一点の測定で果実全体の着色度判定が可能であることを示唆した．一方，グリーンレモンは複数な色分布を持ったことから，正確な着色評価をするには多数な測定点が必要であることを示した．