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Quality Evaluation of Tomato Fruits by Specific Gravity and Color

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The specific gravity, soluble solid content (Brix value), sugar and organic acid contents of harvested tomato fruits were measured. The firmness and surface color of tomato fruits were also determined. The Brix value of tomato fruits was strongly correlated to specific gravity with high coefficient of correlation (r=0.829). The strongly positive correlations were also found between malic acid content and firmness (r=0.800), malic acid content and L* value (r=0.813), whereas malic acid content correlated negatively to a* value (r =–0.807). It was suggested that the soluble solid content of tomato fruits could be determined by specific gravity nondestructively. But the results also showed that there was significant effect of the cavity inside fruit on the specific gravity of tomato fruit. The organic acid expressed high Brix value resulted in remarkable effect on measuring the value of soluble solid content.

INTRODUCTION

In recent years, researches have been focused on the development of non–destructive techniques for measuring quality attributes of tomatoes such as sugar content and firmness (Iwao, et al., 1989; Kawano, et al., 1993; Choi, et al., 1995; Olmo, et al., 2000; Sugiura, et al., 2001). The advantages of these techniques include fast execution, limited sample pre–processing and easy use in process control and grading systems. The maturity and sugar content of harvested tomato fruits is one of the main factors that determined commercial quality. The tomato fruits harvested having a high level of maturation are more susceptible to mechanical damage or infection during their postharvest handling. On the other hand, if the fruits have not developed enough at the time of harvest, it cannot have the sensory characteristics that make it so tempting to the consumer. Therefore, it is important to have method to evaluate tomato fruit maturation stage and quality attributes, especially for sugar content. The method should be cheap, nondestructive and easy to use.

The soluble solid content in the fruit is most widely used as an index to estimate the quality and maturity level of fruits (Yang and Chinnan, 1987). In most fruits, their firm-

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nesses diminish as the degree of maturation increases due to the action of pectin enzymes during fruit maturation (Soda, et al., 1987). Fruit softening is often used as a criterion for selecting the most suitable harvest date for several commodities. The most common method to determine the firmness of fruit is destructive and measures its resistance to penetration. Color is also considered to be one of the most important factors of fruit quality, as the appearance of the fruit greatly influences consumers (Hobson, et al., 1983). During the maturation, tomato fruits change their color owing to chlorophyll degradation and the increase of lycopene and carotenoid (Penelope, et al., 2001). The relationship between color and the level of maturation has been widely studied in tomatoes (Inaba , et al., 1970; Yang and Chinnan, 1987). Hunter color indexes L*, a* and b* are used as being the best parameters for differentiating the different stages of tomato maturity.

The nondestructive method can be applied to determine chemical compositions such as sugar, organic acid contents and firmness as well as in the industry to accurately show the apparent maturation degree of the fruit. This study was done to measure the specific gravity, surface color, firmness, sugar and organic acid contents of tomato fruits and to determine the ability of specific gravity and Hunter color index to effectively predict the soluble solid content in tomato fruits.

MATERIALS AND METHODS

Plant materials

The tomato fruits (*Lycopersicon esculentum* Mill) with different maturity (variety: Momodaro) were harvested from a local greenhouse in Fukuoka Prefecture and transported from the cultivation area to laboratory within 1 h for experiment.

Specific gravity

The volume of each tomato fruit was determined by method of the displace water. Namely, the volume was measured by immersing the tomato fruit in water completely in a 2000 ml beaker that was placed on digital weighing balance (Mettler, PM6100, Tokyo, Japan) with an accuracy of 10^{-2}g. Specific gravity was determined from the volume and weight of tomato fruits and was calculated by using the following equation.

$$SP = \frac{W \cdot \rho}{W_d}$$

Where SP is specific gravity, W is sample weight of tomato fruit (g), ρ is specific density of water (g ml^{-1}), W_d is weight of displaced water in beaker (g).

Firmness

The firmness of each tomato fruit was assessed (after removal of skin) by sclerometer (model FHK, Fuji Hira Industy, LTD, Tokyo, Japan) equipped with an 8–mm diameter plunger. The measurement was carried out at 5 different points (one each at the blossom and stem ends and three in equatorial position) on each tomato fruit. Dial readings were measured in kg .

Color

The surface color of tomato fruit was defined at three points which two points were set along the equatorial region and one point was fixed the top for each tomato fruit with a chromameter (model CR 200; Minolta Corp., Japan). A tristimulus colorimeter with an 11 mm aperture and diffuse illumination (C light source) was calibrated with a white standard calibration plate (Y=92.9, x=0.3136, y=0.3200). Expression of tomato color was characterized as Hunter color indexes L*, a* and b*; where L* indicates the lightness, a* means the color axis from green to red, b* the blue–yellow color axis.

Soluble solid content

The juice of each fruit was extracted by a homogenizer and soluble solid content in the extracted juice was measured using a refractometer (Atago IATC–1E, Osaka, Japan) and expressed in Brix value. 0% was calibrated with distilled water at 20 °C.

Sugar content

Sugar content was determined by HPLC equipped with NH2P–50 column (4.6 mm $\phi \times$250 mm) at 40 °C. The column (Asahipak model, Showa Denko Corp., Tokyo Japan) was packed with SUS 316. The mobile phase was acetonitrile : water=75 : 25 at a flow rate of 1.0 ml min^{-1} and injection volume was 5 μl. Detector is RI. Tomato was cut and homogenized to squeeze juice by homogenizer. The 25 ml sample juice was taken and diluted 10 times with 75% acetonitrile. The homogenate was centrifuged at 3,000$\times$g for 15 min. The supernatant was taken as sample to measure the sugar content.

Organic acid

Organic acid content was also determined using HPLC equipped with Shim–pack SCR–102H column (8 mm $\phi \times$30 cm) (Shimadzu model, Shimadzu Corp., Tokyo Japan) packed with H type cation exchanger that consists of semi–rigid styrene–divinylbenzene copolymer. Detector is RI and temperature is 40 °C. The mobile phase is 0.5 mM *p*–toluenesulfonic acid and flow rate is 1.0 ml min^{-1}. The 25 ml of tomato juice was taken and diluted 5 times with distilled water. The homogenate was centrifuged at 3,000$\times$g for 15 min. The supernatant was taken as sample to measure the content of organic acid.

RESULTS AND DISCUSSION

Correlation between specific gravity and soluble solid content

Fig. 1 shows the relation between specific gravity and Brix value. It indicated that there was high correlation between specific gravity and Brix value with coefficient of correlation (r=0.829). Sugiura et al. (2001) reported that there was high coefficient of correlation (r=0.981) between specific gravity and soluble solid content of grape berries. For tomato fruits, the correlation coefficient was lower than that of grape berries. It was considered that the value of the correlation coefficient might be affected by the range of soluble solid content of the fruit to a certain degree. In the present experiment, the Brix values of tomato fruits were at rather narrow range of 4.1–9.3%, while Brix values of grape berries was wide range of 16.0–23.0% (Sugiura et al., 2001). It was also considered that the effect of cavity inside tomato fruit on specific gravity was another reason for

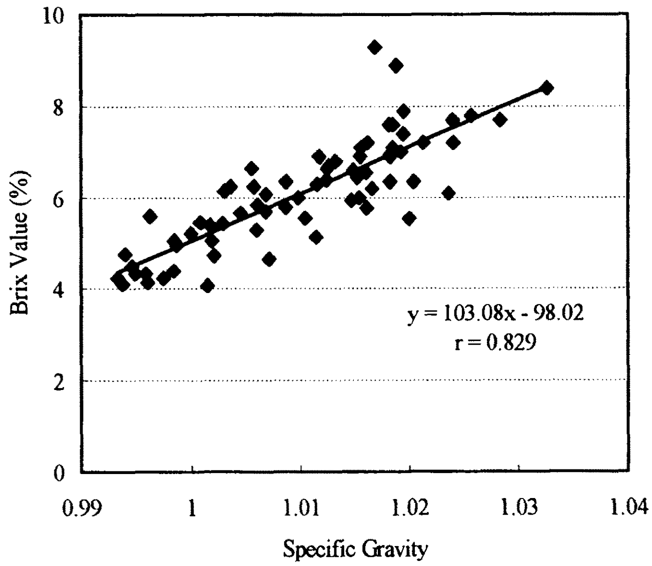

Fig. 1. Relation between specific gravity and Brix value

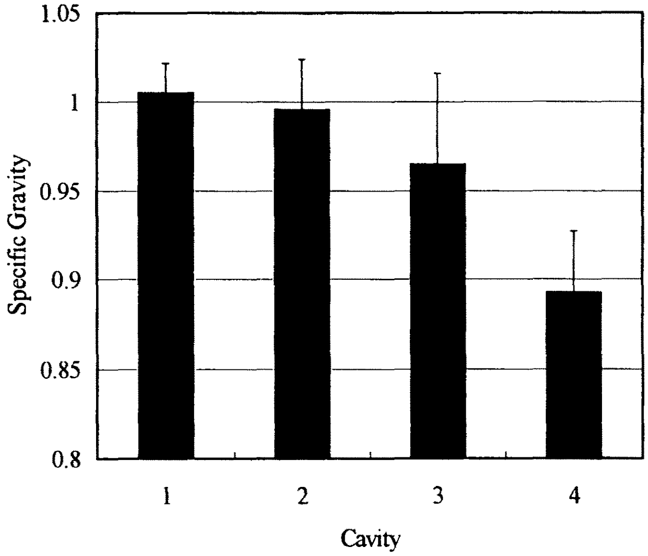

Fig. 2. The effect of cavity on specific gravity of tomato fruits. The evaluation of cavity was scored on a 4-point scale and cavity value of tomato fruits was determined by the distance between endocarp and surface of loculus tissue on the equatorial position: 0=0 mm, 1=1–3 mm, 2=4–6 mm, 3=7–9 mm. Bars represent S. D. values

lower the coefficient of correlation (Fig. 2). Fig. 2 showed that specific gravity was decreased with increase in cavity inside tomato fruits. It was indicated that the specific gravity of tomato fruits was significantly affected by the cavity inside fruit. It was suggested that soluble solid content could not be determined accurately by specific gravity in tomato fruits with cavity. It was appeared that picking period has an important influence on the occurrence of cavities in tomato fruits.

Effect of sugar and organic acid content at various mature stages on Brix value

Fig. 3 shows sugar and malic acid contents at various mature stages of tomato fruits. Total sugar, fructose and glucose contents were increased from mature green to red stage, while they were decreased at mature turning stage. It could be deduced that respiration rate of tomato fruit was reached climacteric maximum at mature turning stage, sugar as respiratory substrate was quickly depleted and resulted in the decrease in sugar content at mature turning stage. The relation between sugar, organic acid contents of tomato fruit and Brix values at different stages was shown in Table 1. It showed that the Brix values were much higher than that of actual sugar contents, the ratio of sugar concentration and Brix value was only 36.1–50.8%. The highest ratio (50.8%) was obtained from mature light-red stage. It was indicated that the expression of Brix value was significantly effected by some chemical compositions such as organic acid and soluble pectin in tomato fruits. It was suggested that Brix value could be as the soluble solid content, but it could not represent sugar content for tomato fruits.

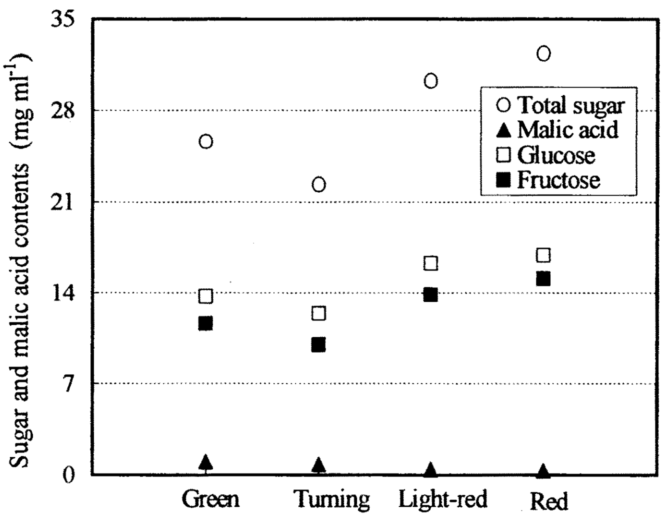

Fig. 3. Sugar and malic acid contents at different maturity stages of tomato fruits

Table 1. Relations between sugar, organic acid contents and Brix values at different mature stages of tomato fruits

Mature Stage	Sugar Content (%) A	Organic Acid Content (%)	Brix Value (%) B	A/B×100 (%)
Red	3.23	0.63	6.83	47.30
Light Red	3.03	0.63	5.96	50.80
Turning	2.23	0.96	6.17	36.10
Green	2.56	0.77	6.41	39.90

Relation between sugar, organic acid concentrations and Brix value

In order to clarify the effect of organic acid on the Brix value and recovery rate of sugar content measured by refractometer, the 3.0–18.0% solutions of fructose, glucose, sucrose, malic acid and citric acid were made and Brix values were measured. The results were shown in Table 2. It indicated that the recoveries over 100% were obtained from 3.0–9.0% fructose, glucose and sucrose solutions. While in 12.0–18.0% sugar solutions, the recoveries were below 100%. It was demonstrated that the Brix value was higher than actual sugar concentrations at lower levels of sugar, while it was lower than actual concentrations at the range of higher sugar levels.

For organic acid, the results showed that organic acids were also expressed high Brix values. The changing trends were similar with Brix values of sugar solutions, namely Brix value of organic solution was higher than actual concentrations at lower levels, while it was lower than actual concentrations at the range of higher levels. It was reasoned that the soluble solid content was much higher than actual sugar content (Table 1) due to the effects of other chemical compositions such as organic acid in tomato fruits.

Table 2. Relations between concentrations of fructose, glucose, sucrose, malic acid, citric acid and their Brix values

Concentration (%) A	Fructose (%) B	B/A×100 (%)	Glucose (%) C	C/A×100 (%)	Sucrose (%) D	D/A×100 (%)	Malic Acid (%) E	E/A×100 (%)	Citric Acid (%) F	F/A×100 (%)
3.0	3.60	120.0	3.07	102.2	3.63	121.1	2.73	91.1	2.97	98.9
6.0	6.53	108.9	6.03	100.6	6.50	108.3	5.03	83.9	5.50	91.7
9.0	9.30	103.3	9.10	101.1	9.37	104.1	7.27	80.7	7.77	86.3
12.0	11.73	97.8	11.83	98.6	12.03	100.3	9.27	77.2	9.87	82.2
15.0	14.30	95.3	14.60	97.3	14.53	96.9	11.13	74.2	11.77	78.4
18.0	17.03	94.6	16.93	94.1	17.73	98.5	13.70	76.1	14.83	82.4

Correlation between organic acid content and firmness

Fig. 4 shows relation between malic acid content and firmness of tomato fruit. There was relative high correlation between malic acid content and firmness of tomato fruit with coefficient of correlation r=0.800. It was indicated that tomato fruits with higher firmness value have relative high organic acid content. The decrease in firmness of tomato fruit

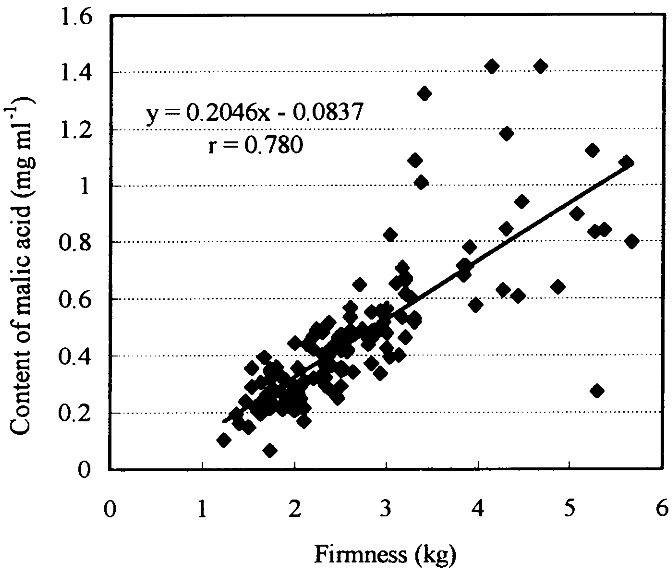

Fig. 4. Relation between malic acid content and firmness of tomato fruits

was accompanied with decrease in organic acid content during maturing and ripening. But it was not found that the correlation between citric acid content and firmness (data not shown). It was suggested that maturity of tomato fruits could be determined by the changes in the firmness and malic acid content.

Correlation between Hunter color L*, a* values and malic acid content

Hunter color L* and a* values were used to determined changes in surface color of tomato fruits as a function of harvest maturity. Relationship between surface color and level of maturation has been widely studied in tomato fruits (Choi, et al., 1995). In this study, it was found that L* value was strong correlation to malic acid content with coefficient of correlation r=0.813 (Fig. 5). L* value was declined with decrease in malic acid content during maturing. It indicated that there were low levels of L* value and organic acid content for mature tomato fruit. The degree of maturity and quality of tomato fruit could be determined by Hunter color value L*. For the relation between a* value and malic acid content (Fig. 6), It was also found the high negative correlation between a* value and malic acid content with coefficient of correlation r=−0.807. When the surface color of tomato fruit was changed from green to red during processing of mature, the a* value was increased, while malic acid content was decreased due to be consumed by physiological metabolism. It was suggested that degree of maturity was not only determined from the a* value, but also malic acid content in tomato fruit could be examined.

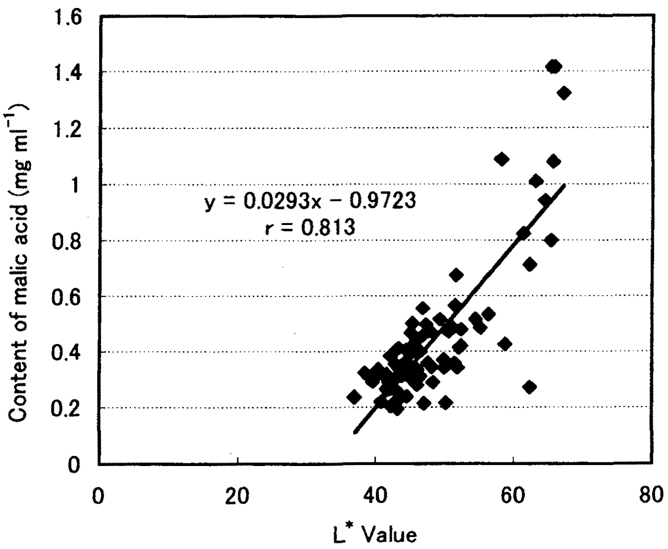

Fig. 5. Relation between malic acid content and L* value

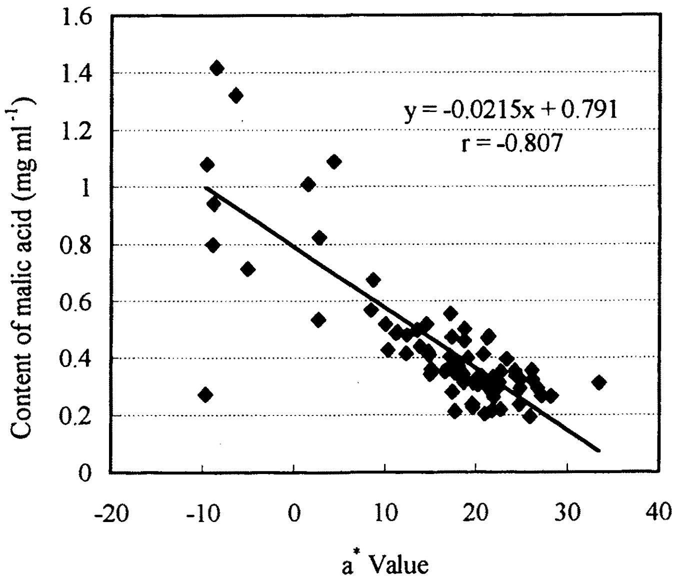

Fig. 6. Relation between malic acid content and a* value

CONCLUSIONS

The soluble solid content of tomato fruits was strongly correlated to specific gravity with relative high coefficient of correlation. The strongly positive correlations were also found between malic acid content and firmness, malic acid content and L* value, whereas malic acid content correlated negatively to a* value. The results showed that there was a significant effect of the cavity inside fruit on the specific gravity of tomato fruit. The organic acid expressed high Brix value resulted in greatly effect on measuring the value of soluble solid content. Brix value could be as the index of soluble solid content and did not express as sugar content in tomato fruit. It was suggested that the soluble solid content of tomato fruits could be determined by specific gravity nondestructively.

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