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Tomato Fruit Quality and Content Depend on Stage of Maturity

Lajos Helyes and Zoltán Pék[1]
Department of Horticulture and Technology, Szent István University, Páter K.út 1., H-2103 Gödölló, Hungary

Andrea Lugasi
National Institute for Food Safety and Nutrition, Gyáli út 3/a H-1097 Budapest, Hungary

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Abstract. **Soluble solids (Brix°), carbohydrate, organic acid, lycopene, polyphenols and HMF content of indeterminate round type tomato Lemance F_1 fruits were measured in six ripeness stages from mature green to deep red stage. Color of fruits was determined by CIELab system. The L*, a*, b* values were received directly and used to calculate from which the a*/b* ratio was calculated. The Brix°, carbohydrate, lycopene and HMF content were the highest in the deep red stage. Carbohydrate contents constitute nearly 50% of the Brix°. The mature green stage had the lowest acid content but in subsequent stages it was fundamentally unchanged. Polyphenol content changed little during fruit ripening. Lycopene content changed significantly during maturation and accumulated mainly in the deep red stage. Analyses showed that a*/b* was closely correlated with lycopene and can be used to characterize stages of maturity in fresh tomatoes.**

Pigment synthesis in tomato is closely related to the initiation and progress of ripening, and the red color of the fruit results from the accumulation of lycopene. Lycopene level of tomato fruit is determined by the genetic potential of the cultivar and environmental conditions, mainly temperature and light. During the ripening period, lycopene content in the fruit increases sharply from the pink stage onward; however, no attempts have been made so far to assess changes in the levels of other antioxidants present in the fruit (Dumas et al., 2003).

Tomato fruits are also rich in polyphenols, which constitute the largest part of the antioxidant content of the soluble solids (Proteggente et al., 2002). George and colleagues (2004) observed a huge variance (104–400 mg·kg^{-1}) in the polyphenol content of different tomato cultivars.

Maillard reaction is a nonenzymatic reaction producing the intermediate compound hydroxymethylfurfural (HMF), which is harmful when consumed by humans. In processed tomato products, HMF content is proportional to lycopene content (Cámara et al., 2003).

The goals of the current study were to examine the effect of maturing process on tomato components and to establish correlations between the levels of components by testing fruit samples at different stages of the ripening process.

Tomato cultivar Lemance F_1 (round fruit; average weight, 110–130 g) grown in a greenhouse in 2004 was investigated in the current study. Sample fruits from six maturity stages [mature green, breaker, turning, pink, red, and deep red, as categorized according to Yamaguchi (1983)], were collected randomly by hand in four replicates, with four fruits in each replicate.

Color measurements were performed on the surface of the tomatoes at three points in the equatorial region of fruits, using the CIELab color measurement system with Sheen Micromatch Plus (Sheen Instruments Ltd, Kingston-Upon-Thames, UK). The L*, a*, and b* values were obtained directly, and were used to calculate the a*/b* ratio.

Fruits from each sampling were washed and homogenized, and the juice samples were stored in a refrigerator at –18 °C until analyses were performed.

Brix value was measured using a refractometer (AST Model 1230, Atago Co. Ltd., Tokyo, Japan). Organic acid content, expressed as grams per kilogram citric acid in fresh weight, was determined according to the Association of Official Analytical Chemists' (AOAC) method 932.12 (Association of Official Analytical Chemists, 1990).

Carbohydrate content was measured after an acidic hydrolysis with HCl at 65 °C for 5 min following the Schoorl–Regenbogen method (Sarudi, 1961). Lycopene from tomato juice was extracted with a mixture of 2 n-hexane : 1 methanol : 1 acetone containing butylated hydroxytoluene (BHT). Optical density of the hexane extract was measured at 502 nm by a Lambda 3B ultraviolet spectrophotometer (Perkin Elmer Life and Analytical Sciences, Wellesley, Mass.) (Sadler et al., 1990). Lycopene levels were calculated by applying the molecular extinction coefficient of 158500 (Merck and Co., 1989). Total polyphenols were analyzed with the Folin–Denis method according to the AOAC official protocol 952.03 (Association of Official Analytical Chemists, 1990).

In addition to the antioxidant compounds mentioned earlier, HMF was also quantified using a colorimetric method based on the thiobarbituric acid color reaction with optical density readings at 443 nm (Guzmán et al., 1986).

The results of the study are shown in Fig. 1. Soluble solids (Brix) content of tomato fruit is determined by the cultivar, the method of cultivation, and the environmental conditions to which the plants have been exposed during the growing process. Brix value was significantly higher (by 12%) in the deep-red stage than in the previous maturity stages. The refraction value of tomato fruit has been established to correlate positively with the levels of valuable nutritive components as well as with the flavor of the fruit.

Carbohydrates accounted for 50% to 55% of the soluble solids in tomato fruit. Similar to Brix value, carbohydrate content of the fruits was the highest in the deep-red stage (3%). This value was 23% higher than in the mature green stage.

Organic acid content was the lowest in the mature green phase (3.7‰). In the next stage it increased and remained almost at the same level during the following ripening stages, yielding an average value of 4.7‰. Polyphenol content of the fruits ranged from 33 to 48 mg·100 g^{-1}. The lowest and highest values were found in fruits from the mature stage and at the pink stage respectively. Polyphenol content of the fruits did not change significantly during the ripening process.

In this study, during the mature green stage, the fruit contained a small amount of lycopene that was barely detectable. In subsequent maturity stages, lycopene content of the fruits increased. Almost half the total lycopene content (46%) is synthesized and accumulated during the deep-red stage. The color of the fruits is an important consumer quality, with a strong preference for deep-red ripe tomatoes. The majority of tomatoes produced for fresh consumption are sold before their full maturity (pink and red stages), and relatively few of them are marketed as completely deep-red tomatoes. Linear regressions of color readings and maturity stages produced the best fit (R = 0.94; not shown).

The quantity of HMF in the fruits ranged from 35 to 79 µmol·kg^{-1} depending on maturity stages. The value of HMF was doubled from mature green stage to deep-red stage.

Table 1 summarizes the correlation coefficients of linear regressions of each investigated component or parameter in all maturity stages.

The color parameter a*/b* ratio correlated positively with carbohydrate, lycopene, and HMF contents. Linear regression of the a*/b* ratio of maturity stages and lycopene content produced a good fit (R = 0.89). This is in

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[1]To whom reprint requests should be addressed; e-mail Pek.Zoltan@mkk.szie.hu.

Table 1. Correlation coefficients of linear regression between ingredients and parameters of tomato fruit (n = 72) investigated in six maturity stages.

	Brix	Carbohydrate	Organic acid	Polyphenols	Lycopene	HMF	a*/b* ratio	Chroma
Brix (°)		0.68***	0.44	–0.22	0.5*	0.08	0.42	0.32
Carbohydrate			0.32	–0.03	0.62***	0.39	0.49*	0.34
Organic acid				0.44	0.23	0.12	0.3	0.35
Polyphenols					–0.06	0.61**	0.05	–0.07
Lycopene						0.47	0.89***	0.67***
HMF							0.49*	0.35
a*/b* ratio								0.85***
Chroma								

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.
HMF, hydroxymethylfurfural.

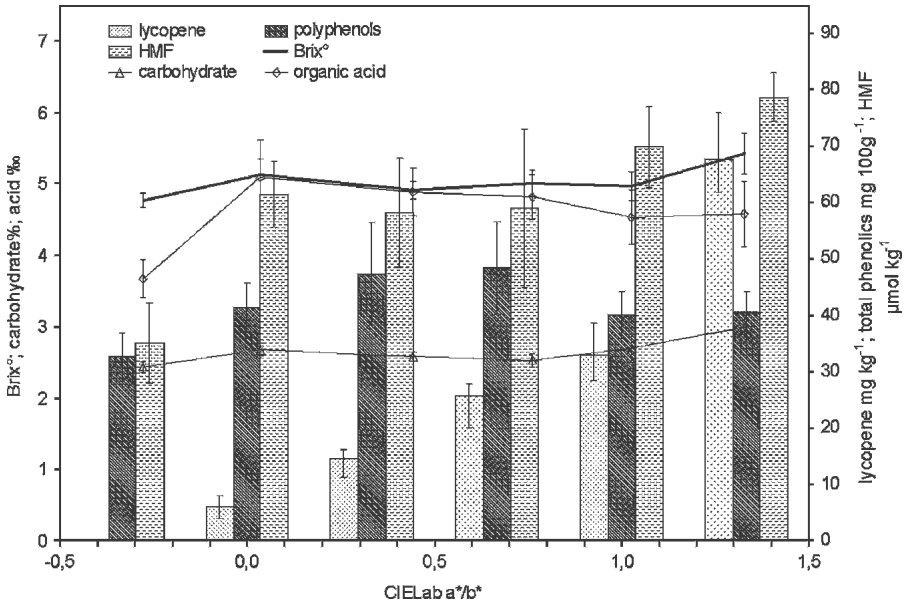

Fig. 1. Changes in the content of fruit components as a function of a*/b* ratio (mean ± SD; n = 12).

agreement with the finding of Arias et al. (2000), although the curve that best fits the measurement data of these parameters could be described by an exponential regression.

Brix value only correlates positively with carbohydrate and lycopene content. Polyphenol content highly correlated only with HMF content. HMF cannot only be formed during processing, because fresh tomato also contains detectable quantities of HMF. However, it does not represent any risk in terms of human consumption.

Our results show that the a*/b* ratio is a suitable parameter to characterize the maturity stages and lycopene content of tomato fruits. The Brix value might also be used to characterize the different maturity stages.

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