BrimA, Total Acidity and Total Soluble Solids Correlate to Total Carotenoid Content as Indicators of the Ripening Process of Six Thai Mango Fruit Cultivars

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ABSTRACT

This investigation was carried out to correlate BrimA values with total carotenoid content (TCC) in comparison to TSS (total soluble solid) / TA (total acidity) ratios and TA with TCC of six mango (Mangifera indica L.) cultivars: "Kaew," "Khew Sawoey," "Chok-Anan," "Nam Dok Mai," "Maha-Chanok," and "Nang Klangwan." Mature green mango fruits were selected based on having a specific gravity greater than 1.0 and then kept at 25±2°C with 70-80% RH. The sampling was carried out randomly on a daily basis until the mango fruits ripened. For all cultivars, the BrimA value, TSS/TA ratios, and TCC increased during the ripening process. The correlation coefficients (r^2) suggested that TCC was highly related to BrimA values rather than TSS/TA ratios and TA in some cultivars. The best corresponding r^2 values of BrimA and TCC were 0.88 and 0.99 for cv. Kaew and Nang Klangwan, respectively. Therefore, correlation between BrimA and TCC may be useful as an index for determining the ripening stage, flesh color, and sweetness of mango fruit.

Keywords: TSS/TA ratio, Ripening index, BrimA, Carotenoid content, Mango fruit

INTRODUCTION

Mangoes are grown in every part of Thailand and are an important economic fruit. The popular mango cultivars for export include cv. Kaew, Khew Sawoey, Chok-Anan, Nam Dok Mai, Maha-Chanok and Nang Klangwan. The main export markets are Malaysia, Japan, Indonesia, Singapore, China, and the European Union (Chomchalow, 2008). The quality and storage life of the mango fruit depend on the degree of maturity at the time of harvesting because harvesting the mango fruit at an immature stage leads to low quality and a short

storage life at the ripened stage (Jain et al., 2003; Crane, 2009). The mango fruit is a climacteric fruit, meaning the fruit is best harvested at a mature stage when it will then ripen to good quality. During ripening, many physicochemical changes occur including decreasing starch and acid content and increasing total sugar and carotenoid content (Keryl et al., 1998). Some cultivars of mango fruit are generally consumed at the ripened stages, such as Chok-Anan, Nam Dok Mai, and Maha-Chanok, while others because of their high starch and low acid content are consumed at the mature green stage, such as Khew Sawoey, Pimsen Man, and Falan (Ian, 2010).

A harvesting index of mango fruit is, therefore, very important. The common harvesting indices are age of fruit, specific gravity, size and shape, total soluble solid (TSS), total acidity (TA) and TSS/TA ratio (Will et al., 1998). The TSS/TA ratio is determined by dividing the % TSS by % TA, expressed to the first decimal. A value of 14, for example, indicates a sample with 14 parts soluble solid and one part acid. The higher the value or ratio the sweeter the taste and vice-versa (Ranganna, 1986). However, no suitable index exists for comparing a mango's ripeness to taste measures.

Recently, New Zealand investigators suggested a new index in which the Brix reading is modified to account for the sweetness-reducing effect of the acids present. This index is based on the linear weighed difference between the Brix and TA measure rather than their ratio. They call this index BrimA (pronounced "bree-mah" for Brix minus Acid. BrimA = TSS - (k x total acidity) where k is a constant that may vary between fruit species or cultivars due to differing mixes of acids and sugars, such as about 5.0 for citrus and grapes (Jordan et al., 2001; Obenland et al., 2009). The objective of this research is to compare the correlations between TSS/TA and TCC, TA and TCC, and BrimA and TCC for use as an index for ripening stages of mango fruit.

MATERIALS AND METHODS

Plants materials

Mature green mango fruits of six cultivars (cv. Kaew, Khew Sawoey, Chok-Anan, Nam Dok Mai, Maha-Chanok, and Nang Klangwan) were harvested from commercial orchards in Sansai District, Chiang Mai Province, Thailand from April to July 2008. Mature green mango fruits were selected for uniform maturity based on a specific gravity greater than 1.0 by sinking in a tub of water.

Methods

The mango fruit ripened under controlled conditions at 25+2OC with 70-80% RH for ripening. The fruits were randomly sampled on a daily basis until over-ripened. The samples were prepared as follows. Ten gm of mango flesh were mixed in 100 ml distilled water and titrated with 0.1 N NaOH solution to pH 8.1. Titratable acidity was expressed as % citric acid per 100 g fresh weight basis (fw) (Ranganna, 1986). TSS was measured using a digital refractometer (Model PR-101, Atago Co. Ltd) from fresh hand-squeezed mango juice. The TSS/TA

ratios were calculated from TA and TSS values. BrimA was calculated from the relationship BrimA = TSS - (k x TA), where k = 5 (Jordan, 2001). Total carotenoid was extracted from mango flesh by 40% acetone in hexane, then absorbance at 450 nm was measured by spectrophotometer (Spectrophotometer, SPECORD 40, Analytik Jena,Germany), using beta-carotene as the standard (Ranganna, 1986). All determinations were done in triplicate. The correlation coefficients between TSS/TA ratios and TCC, TA and TCC, and BrimA and TCC were calculated from various graphs.

Statistical analysis

The averages were analyzed using a completely randomized design with 5% confidence level (p=0.05). When significant differences were found, Turkey's multiple range test was applied. All statistical analyses were carried out using SPSS software package version 15.

RESULTS AND DISCUSSION

The results for TSS, TA, TSS/TA, BrimA, and TCC at different ripening stages of the mangoes from different cultivars are presented in Tables 1 and Figure 1 (A-D) and Figure 2. For all cultivars, as the mango ripened, TSS, TSS/TA ratio, BrimA, and TCC increased. Cultivar Chok Anan showed the highest TSS increase. In turn, TA for all cultivars decreased during the ripening process, with cv. Nam Dok Mai showing a dramatic 24-fold decrease.

In comparing the mature green and ripened stages of each cultivar, cv. Kaew had the lowest TSS/TA ratio of 3.2 and 92.6, mature green to over-ripened, respectively. Mango fruit cv. Khew Sawoey had the highest TSS/TA ratio of 39.5 and 271.4, respectively (Table 1). BrimA, calculated from TSS and TA, was the lowest in the unripe mango fruit of cv. Kaew (-5.8) and highest in cv Khew Sawoey (12.5). In ripened mango fruit, cv. Nang Klangwan had the lowest BrimA (14.8) and Chok-Anan the highest (20.5) (Table 1). All cultivars of mature green mango fruit had low TCC and it increased during ripening (Figure 2). Ripened mango fruit cv. Maha-Chanok had the highest TCC (85.5 ug/gfw) and cv. Chok-Anan had the lowest (52.1 ug/gfw).

During fruit ripening, the acidity decreases and the total solids and total carotenoid content increase. TA and TSS are easily measured, but TCC is difficult to measure under field conditions. Therefore, a ripening index needs to be constructed using the easily-accessible parameters, TA and TSS, as a function of the difficult-to-get TCC. Three indices are possible, TA, TSS, and a relationship between the two as TSS/TA or BrimA. A good correlation is indicated by a coefficient close to 1.0.

The correlation coefficients (r^2) between TSS/TA, TA, and BrimA with TCC are shown in Table 2. TA and TCC had a negative correlation, in agreement with the literature. Some cultivars had a more positive correlation between BrimA and TCC than either the TSS/TA ratio or TA. The r^2 of cv. Chok-Anan (0.96) and Nang Klangwan (0.99) were close to 1. This means that BrimA highly correlated

to TCC for these two cultivars. For the other cultivars, cv. Khew Sawoey and Nam Dok Mai, the correlation was not as good, with the TSS/TA ratio providing a better correlation. It is interesting to note that for unripe mango fruit used as such for consumption, such as cv. Khew Sawoey, the correlation of TSS/TA ratio and TCC was better than the correlation of BrimA and TA. An explanation for the r^2 of BrimA and TCC being low for this cultivar might be a low TA and high TSS. This result is similar to an investigation of sensory evaluation in apple fruit (cv. Golden Delicious). TSS/TA ratios better explained the sweet and acid tastes perceived by consumers than BrimA, because apples have a low acid content (Harker et al., 2002). However, Obenland et al. (2009) reported that BrimA could be used as a maturity index for oranges, correlating to a hedonic score more than the TSS/TA ratio and better related to the color of the orange peel.

Even though BrimA correlated very well with TCC for some cultivars, for others this correlation was weak. Nevertheless, in comparing the data, the overall correlation of BrimA with TCC was good across the six cultivars studied. Because TCC of mango fruit increased during ripening, the correlation of BrimA and TCC may provide a useful index for the ripening stages of mango fruit.

Table 1. %TSS, %TA, TSS/TA ratio, BrimA, and Carotenoid of six mango cultivars at five different ripening stages.

Cultivar	Composition	Mature green	Breaker	Turning	Ripening	Ripened
Chok-Anan	% TSS	7.09^{b}	15.37^{d}	19.77^{e}	22.17^{e}	21.20^{e}
	% TA	1.01^{b}	0.79^{c}	0.40^{c}	0.26^{b}	0.14^{b}
	TSS/TA ratio	7.04^{d}	19.46^{d}	49.43^{d}	85.27^{d}	151.43^{d}
	BrimA	2.05^{e}	11.42^{d}	17.77^{f}	20.87^{f}	20.50^{f}
	Carotenoids	8.97^{a}	22.22^{b}	35.22^{a}	47.24^{a}	52.10^{a}
Kaew	% TSS	10.54^{d}	14.88^{c}	16.28^{b}	16.62^{b}	18.06^{b}
	% TA	3.26^{f}	1.56^{f}	0.44^{e}	0.44^{c}	0.20^{c}
	TSS/TA ratio	3.23^{a}	9.54^{b}	37.00^{c}	37.77^{b}	92.62^{b}
	BrimA	-5.76^{a}	7.08^{c}	14.08^{c}	14.42^{c}	17.09^{c}
	Carotenoids	15.49^{b}	35.50^{c}	54.99^{d}	70.45^{c}	80.09^{c}
Khew Sawoey	% TSS	14.33^{f}	17.74^{f}	17.96^{d}	18.42^{d}	19.00^{d}
	% TA	0.36^{a}	0.15^{a}	0.10^{a}	0.09^{a}	0.07^{a}
	TSS/TA ratio	39.50^{e}	118.27^{f}	179.60^{f}	204.67^{f}	271.43^{f}
	BrimA	12.52^{f}	16.06^{f}	17.46^{e}	17.97^{e}	18.65^{e}
	Carotenoids	17.27^{bc}	24.67^{b}	40.50^{c}	49.99^{a}	68.38^{b}
Maha-Chanok	% TSS	8.5^{c}	11.70^{b}	16.33^{b}	16.63^{b}	17.95^{b}
	% TA	1.31^{c}	1.17^{d}	0.77^{d}	0.65^{d}	0.20^{c}
	TSS/TA ratio	6.51^{d}	10.00^{c}	21.21^{b}	25.58^{a}	87.98^{a}
	BrimA	1.97^{d}	5.85^{b}	12.48^{b}	13.38^{b}	16.93^{b}
	Carotenoids	22.33^{d}	37.29^{d}	63.56^{e}	73.78^{c}	85.45^{d}
Nam Dok Mai	% TSS	12.32^{e}	17.12^{e}	17.33^{c}	17.56^{c}	18.37^{c}
	% TA	2.38^{e}	0.48^{b}	0.21^{b}	0.10^{a}	0.10^{a}
	TSS/TA ratio	5.18^{c}	35.67^{e}	82.52^{e}	175.60^{e}	183.73^{e}
	BrimA	0.43^{c}	14.72^{e}	16.28^{d}	17.06^{d}	17.87^{d}
	Carotenoids	17.05^{bc}	26.91^{bc}	55.65^{d}	62.55^{b}	82.80^{c}
Nang Klangwan	% TSS	6.12^{a}	11.01^{a}	13.77^{a}	13.89^{a}	15.50^{a}
	% TA	1.43^{d}	1.38^{e}	0.82^{d}	0.24^{b}	0.14^{b}
	TSS/TA ratio	4.29^{b}	8.01^{a}	16.79^{a}	59.09^{c}	110.71^{c}
	BrimA	-1.01^{b}	4.14^{a}	9.67^{a}	12.71^{a}	14.80^{a}
	Carotenoids	19.23^{bc}	18.91^{a}	39.68^{ab}	64.96^{b}	82.87^{c}

Table 2. Correlation coefficients (r^2) between TSS/TA ratio, TA, and BrimA with TCC during fruit ripening of six mango cultivars at five different ripening stages.

Cultivar	r^2 values between TSS/TA ratio and TCC	r^2 values between TA and TCC	r^2 values between BrimA and TCC
Chok-Anan	0.80	0.99	0.96
Kaew	0.86	0.86	0.88
Khew Sawoey	0.94	0.63	0.76
Maha-Chanok	0.87	0.94	0.86
Nam Dok Mai	0.83	0.76	0.77
Nang Klangwan	0.77	0.94	0.99

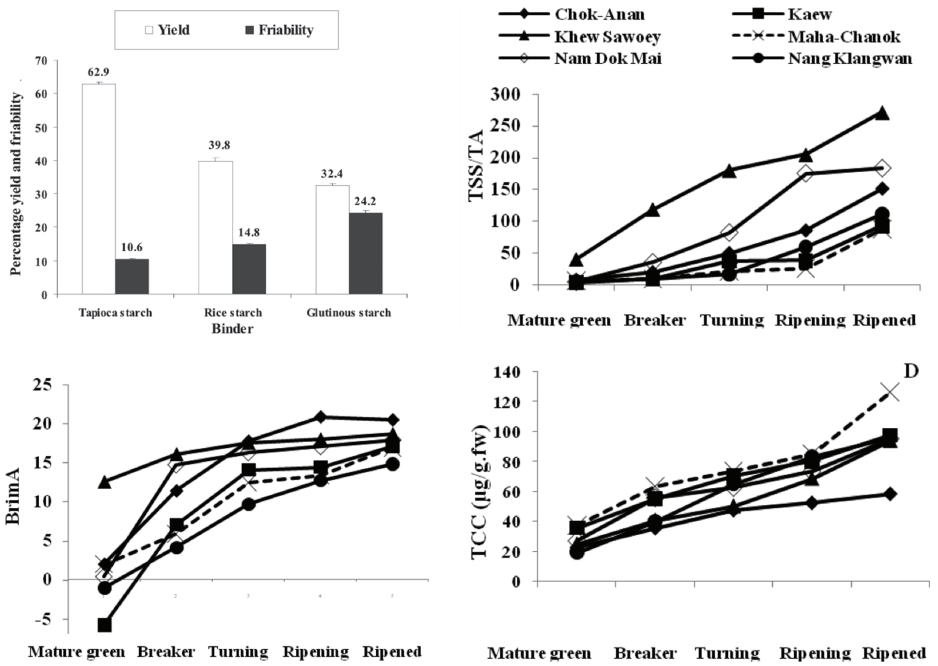

Figure 1. %TSS (A), TSS/TA ratio (B), BrimA (C), and TCC (D) during fruit ripening of six mango cultivars at five different ripening stages.

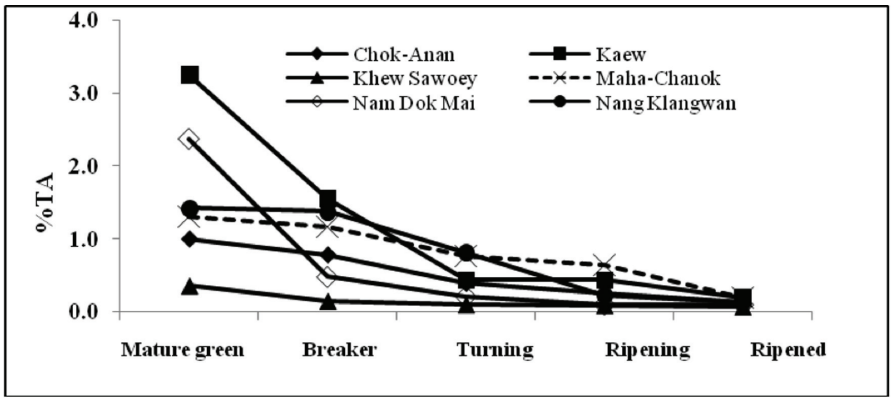

Figure 2. %TA changes during fruit ripening of six mango cultivars at five different ripening stages.

CONCLUSION

For some cultivars of mango fruit, BrimA and TCC correlate better than either TA and/or TSS/TA with TCC. For these cultivars, a BrimA and TCC graph or table may provide a useful index for evaluating the ripening stage of mango fruit in the field.

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