ผลของพันธุ์และสภาพแวดล้อมต่อคุณภาพและสารต้านอนุมูลอิสระในมะเขือเทศ

Effects of Varieties and Environments on Quality and Antioxidants of Tomato

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บทคัดย่อ

มะเขือเทศเป็นพืชที่อุดมไปด้วยสารออกฤทธิ์ทางชีวภาพที่สำคัญหลายชนิด เช่น วิตามินเอ แคโรทีนอยด์ สารประกอบฟีนอลิก และวิตามินซี ซึ่งปริมาณสารต้านอนุมูลอิสระในมะเขือเทศขึ้นอยู่กับหลายปัจจัย ได้แก่ พันธุกรรม และสิ่งแวดล้อม (อุณหภูมิ ความเข้มแสง และความชื้น) ซึ่งการทดลองนี้มีวัตถุประสงค์เพื่อประเมินความแตกต่างของคุณภาพผลผลิต และสารต้านอนุมูลอิสระ ของมะเขือเทศที่ปลูกในโรงเรือนที่มีสภาพแวดล้อมที่แตกต่างกัน โดยใช้มะเขือเทศ 9 พันธุ์ (มะเขือเทศเชอร์รี่ 3 พันธุ์ และ non–cherry 6 พันธุ์) เพื่อประเมินคุณภาพผลผลิต และฤทธิ์การต้านอนุมูลอิสระ ปลูกภายใต้โรงเรือนที่แตกต่างกัน 2 แบบ คือ โรงเรือนปลูกพืชแบบปรับอากาศ (E1) และโรงเรือนปลูกพืชแบบเปิด (E2) วางแผนการทดลองแบบสุ่มสมบูรณ์ภายในบลอค (RCBD) จำนวน 3 ซ้ำ ทำการบันทึกดัชนีสี ปริมาณของแข็งที่ละลายน้ำได้ (TSS) ปริมาณไลโคปีน และฤทธิ์การต้านอนุมูลอิสระ ผลการทดลองพบว่าพันธุ์ (9 พันธุ์) และสภาพแวดล้อมในโรงเรือนทั้ง 2 แบบ ส่งผลให้มะเขือเทศมีลักษณะต่างๆ แตกต่างกัน โดยพบว่ามะเขือเทศที่ปลูกในสภาพแวดล้อม E1 มีค่า TSS ปริมาณไลโคปีน และฤทธิ์การต้านอนุมูลอิสระ สูงกว่าสภาพแวดล้อม E2 สำหรับผลของพันธุกรรมพบว่ามะเขือเทศเชอร์รี่มีปริมาณ TSS สูงกว่ามะเขือเทศชนิด non–cherry แต่พันธุ์ที่มีปริมาณไลโคปีนสูงสุดในทั้งสองสภาพแวดล้อมคือพันธุ์ลูกท้อ (12.22 และ 5.83 mg/100 g FW) และพันธุ์เรนส์เจอร์ (13.11 และ 4.38 mg/100 g FW) ส่วนฤทธิ์การต้านอนุมูลอิสระพบค่าสูงที่สุดในพันธุ์สวีทเชอร์รี่ 154 และพันธุ์สวีทบอย ที่ปลูกในสภาพแวดล้อม E1 (74.58 และ 76.36 μM TE/100g FW) นอกจากนี้ยังพบว่าปริมาณไลโคปีนมีความสัมพันธ์เชิงบวกกับค่าความเป็นสีแดง (a*) แต่ไม่มีความสัมพันธ์กับฤทธิ์การต้านอนุมูลอิสระ

ABSTRACT

Tomato is an abundant source of bioactive compounds including vitamin A, carotenoids, phenolic compounds and ascorbic acid. The antioxidant content in tomato is dependent on several factors including genetic and environments (temperature, light intensity and humidity). The aim of this study was to evaluate variations in the antioxidants of tomato varieties under different greenhouse conditions. Nine tomato varieties comprised of three cherry tomatoes and six non–cherry tomatoes were investigated for yield quality and antioxidant content under two greenhouse conditions i.e. evaporation greenhouse (E1) and uncontrollable condition greenhouse (E2). In each greenhouse condition, the experimental design was a RCBD with three replications. Data collection included fruit color index, total soluble solids (TSS), lycopene and antioxidant activity. The results showed that both genotypes (9 varieties) and environments were significantly affected all traits. TSS, lycopene and antioxidant activities of tomatoes grown under E1 was higher than E2. For genetic effects, it revealed that TSS of cherry was higher than non–cherry tomatoes. The highest lycopene contents in E1 and E2 environments were found in Loog Too (12.22 and 5.83 mg/100 g FW, respectively) and Ranger (13.11 and 4.38 mg/100 g FW). In addition, Sweet Cherry 154 and Sweet Boy had the highest antioxidant activities in E1 (74.58 and 76.36 µM TE/100g FW, respectively). Lycopene content had a positive correlation with fruit redness (a*) but had no significant correlation with antioxidant activity.

คำสำคัญ: ไลโคปีน ฤทธิ์การต้านอนุมูลอิสระ มะเขือเทศเชอร์รี่
Keywords: Lycopene, Antioxidant activity, Cherry tomato

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is an important commercial fruit vegetable and is widely cultivated in Thailand where the area and total production of tomato was about 6,028 ha and 122,593 tons, respectively, and it productivity was about 21.88 tons/ha during 2016–2017. Sixty seven percent of tomatoes are used as raw material in tomato processing industries and 33% are shipped to fresh market (Office of Agricultural Economics, 2017). Tomato is a source of minerals, organic acids and antioxidants such as vitamin C, vitamin E and phenolic compound (Mattila and Hellström, 2007). Lycopene that is one of the common carotenoids is main pigment and widely present in mature tomatoes (Nguyen and Schwartz, 1999) and it is fairly stable to storage and cooking. It is known that the content of each antioxidant in vegetables is strongly influenced by different varieties as well as agronomical and environmental factors (Abushita et al., 2000; Raffo et al., 2002; George et al., 2004). The previous studies reported that the antioxidant content of interspecific tomato plants had variability where *L. pimpinellifolium* was significantly higher than *L. esculentum* (Hanson et al., 2004). The antioxidant content of intraspecific tomato also had variability between cherry and non–cherry tomato (*L. esculentum*). It was reported that 76 varieties of non–cherry tomato were derived from commercial varieties and their germplasm lines produced ß–carotene ranging from 29.7–173.1 mg/kg and lycopene from 386.8–2,067.1 mg/kg, which were higher than cherry tomato. Bhandari et al. (2016) also reported that the germplasm lines of cherry tomato have higher vitamin C and total phenolic compound than non–cherry tomato. Furthermore, the maturing stages of tomato also have effects on both antioxidant content of interspecific and intraspecific variability (Riadh et al., 2016). Beside genetic effects, antioxidant accumulation in tomato can be affected by environmental factors, such as soil, climate, growing season, agricultural practice and postharvest. Various research reported that antioxidants increased with appropriate nutrient, temperature, light quality and light intensity (Ilić et al., 2012; Leyva et al., 2013; Zhang et al., 2017). Therefore, improvement of environmental management is an important aspect for improving the quality tomatoes. Leyva et al. (2013) studied effect of climatic control of greenhouse on tomato nutrition, and found that under the highest of relative humidity (72.1%) and lowest temperature (32.4°C) condition, lycopene content and antioxidant activity of tomato can be increased. Light intensity and light quality affect plant growth and development, as well as antioxidants. Ilić et al. (2012) reported red and blue shade nets in open field (1,594 µmole/m^2/s) and plastic–house (1,112 µmole/m^2/s light intensity) produced high lycopene content and low β–carotene in tomato. In addition, the previous study of Zhang et al. (2017) using the combination of red (660 nm) and blue light (460 nm) in the ratio of 2:1 in tomato after flowering produced the highest content of lycopene of fresh weight (30 µg/g). Therefore, improving quality of tomato fruit has become more important in tomato production. The aim of this study was to evaluate variations in the antioxidants of 9 varieties of tomato characterized by a high content of antioxidants in different greenhouse conditions.

MATERIALS AND METHODS

1. Experimental design and plant materials

The greenhouse experiments were conducted in a RCBD with three replications and each treatment included 30 plants at Suranaree University of Technology Farm, Nakhon Ratchasima, Thailand. The first condition was performed in an evaporation cooling greenhouse with an average relative humidity of 78 %RH and temperature raged from 28–35°C (July–October 2018). Second environmental condition was uncontrollable environment greenhouse with humidity of 62 %RH and average temperature between 35C40°C (December 2018– March 2019). The relative humidity and temperature were collected daily after the experiment began. Seed of 3 cherry tomatoes (Sweet Cherry 154, Sweet Girl and Sweet Boy) and 6 non–cherry tomatoes (Petchchomphu F1, Sida Namkhem, Petch Rung, Sida, Loog Too and Ranger) were germinated in peat moss pots (Table 1). One–month–old seedlings were transplanted to growing bags (8×16 inch) which contained coconut coir and coconut bark. The spacing between and within rows were 50 cm and 50 cm, respectively. Drip irrigation with nutrient solutions (solution A and B) were applied twice a day. The solution A consisted of $Ca(NO_3)_2$ (354 ppm), Fe–EDDHA (0.12 ppm) and Fe–EDTA (5.3 ppm), and the solution B consisted of KNO_3 (302 ppm), KH_2PO_4 (135 ppm), $MgSO_4$ (135 ppm) and completed micronutrients (Nickspray, 4.3 ppm). Pest management was carried out according to local standard practice . Biometrical observations were recorded from 15 random plants in each treatment.

2. Data collection

2.1. Fruit color index and total soluble solids

At the ripening stage (45 days after anthesis), fruit color index and total soluble solids (TSS) were determined. Three randomly samples of two fruits on second bunch were measure in each treatment. Fruit color was measured using CR–400 Chroma Meter and TSS (°brix) was determined using refractometer.

2.2 Lycopene content

Tomato fruits at the red–ripe stage, 45 days after anthesis, were randomly selected for analysis with three replicates of two fruits on second bunch. Ripe fruits were harvested and immediately analyzed for lycopene content according to the method of Sadler et al. (1990). Lycopene content expressed as mg/kg FW base on a lycopene standard curve.

2.3 Antioxidant activity

Tomato fruits at the red– ripe stage, 45 days after anthesis, were randomly selected for analysis with three replicates of two fruits on second bunch. Ripe fruits were harvested and immediately analysed for antioxidant activities (DPPH° scavenging assay), which were analysed according to the method of Erge and Karadeniz (2011). The antioxidant activity was determined as the basis of percent quenching of DPPH radical and expressed as the decreasing percent absorbance of the DPPH radical solution by using the following equation (1).

$$\text{A. A. } (\%) = \frac{(\text{Control absorbance} \times \text{Sample absorbance})}{\text{Control absorbance}} \qquad (1)$$

Results were analyzed by linear regression of the standard curves at 500, 1,000, 1,500 and 2,000 μM of trolox. Antioxidant activities were determined as μM trolox equivalent per 100 g FW (μM TE/100 g FW).

3. Data analysis

Means of total soluble solids, fruit color index, lycopene content and antioxidant activity were assessed by analysis of variance (ANOVA) using SPSS v1 .4 for window. When a significant difference detected, means were compared using multiple comparisons by DMRT.

RESULTS

1. Fruit color index

Fruit color index of tomato can be expressed in numerical term of L* (lightness), a* (redness) and b* (yellowness), which were presented in Table 1. The results showed the effect of varieties and environments on fruit color index of tomato were significant differences. The L* values varied among varieties from 33.29–44.52 but were not significant differences between environments. There were significant differences in a* values between conditions and among varieties. The results indicated that a* value in the E1 (22.64) was higher than that in E2 (18.67) conditions. The highest average a* in both environments was found in Loog Too (28.08) and Ranger (25.27). Some non–cherry tomato such as Petchchomphu F1, Sida and Sida Namkhem, which have pink fruit color, had low value of the a* value (16.59, 19.86 and 21.28, respectively). The b* values showed highly significant differences among varieties. Cherry tomato var. Sweet Boy showed the highest b*values (yellowness) under both environments (20.09 and 22.44) (Table 2).

2. Total soluble solids (TSS)

The TSS of different varieties under E1 and E2 conditions was shown in Table 1. TSS of all varieties under the E1 (4.93 °brix) were higher than under E2 conditions (4.38 °brix). Means comparison among varieties, the TSS of var. Sweet Boy (6.82 °brix) and Sweet Girl (6.40 °brix) was the highest under both conditions (Table 1). TSS of cherry tomato of E2 varied from 4.57–5.83 °brix

3. Lycopene content

Lycopene content of tomato varieties in both conditions were presented in Table 1. All varieties in E2 condition (4.00 mg /100 g FW) had lower lycopene content than those in E1 (8.74 mg/100 g FW). Lycopene content of non–cherry tomatoes varied from 5.14–9.03 mg/100 g FW, which was higher than cherry tomato (ranged from 0.54–7.54 mg/100 g FW). The lycopene content showed significant differences among varieties in two environments (Table 2). The highest lycopene content in E1 was found in Loog Too and Ranger varieties (12.22 and 13.11 mg/100 g FW, respectively), while the lowest was found in Sweet Boy (0.46 and 0.60 mg/100 g FW in E1 and E2 conditions, respectively).

4. Antioxidant activity

The antioxidant activity of tomato varieties was shown in Table 2. The results showed significant differences of antioxidant activity among tomato varieties in both conditions. In E1 condition, antioxidant activity values varied from 46.03–76.36 μM TE 100gFW. The highest DPPH was found in Sweet Boy and Sweet Cherry 154 (76.36 and 74.58 μM TE/ 100g FW, respectively). In the E2 condition DPPH values varied from 55.65–57.55 µM TE/100g FW. Sweet Boy had the highest antioxidant activity with 76.36 µM TE/100g FW. Generally, antioxidant activity of tomato in E1 (61.26 µM TE/100g FW) were higher than in E2 conditions (56.49 µM TE/100g FW) (Table 1).

5. Correlation between quality and antioxidants

The correlation coefficients of fruit quality and antioxidants were estimated for cherry and non–cherry tomatoes (Table 3 and Table 4). The results indicated that lycopene content was positively correlated with the a* value in both cherry and non–cherry tomatoes, but it had highly negative correlation with b* value in cherry tomato. Lycopene content had no correlation with DPPH and TSS in both types. Furthermore, TSS had positive correlation with DPPH in cherry tomato but had no correlation in non–cherry tomato.

Table 1. Fruit color index, TSS, lycopene and antioxidant activity of tomatoes under 2 environments.

	Fruit color index			TSS	Lycopene	Antioxidant activity
	L*	a*	b*	(°brix)	(mg/100 g FW)	(µM TE/100g FW)
Environment (E)						
E1	37.13	22.64^{a}	13.44	4.93^{a}	8.74^{a}	61.26^{a}
E2	42.19	18.67^{b}	14.33	4.38^{b}	4.00^{b}	56.49^{b}
p–value	ns	*	ns	*	**	*
Varieties						
Sweet Cherry 154	42.64	21.60^{abc}	14.65^{bcd}	5.32^{b}	6.51^{ab}	65.12^{a}
Sweet Girl	33.29	19.79^{bc}	12.07^{def}	6.40^{a}	7.54^{ab}	59.26^{abc}
Sweet Boy	43.06	9.19^{d}	21.26^{a}	6.82^{a}	0.54^{c}	66.96^{a}
Petchchomphu F1	40.55	16.59^{c}	10.22^{ef}	3.77^{c}	5.14^{b}	59.80^{abc}
Sida Namkhem	44.52	21.28^{bc}	11.63^{def}	3.87^{c}	6.85^{ab}	62.04^{ab}
Petch Rung	39.42	22.65^{abc}	12.90^{cde}	4.08^{c}	6.57^{ab}	51.34^{c}
Sida	41.03	19.86^{bc}	9.74^{f}	3.50^{c}	6.43^{ab}	54.29^{bc}
Loog Too	35.18	28.08^{a}	15.58^{bc}	4.20^{c}	9.03^{a}	52.41^{bc}
Ranger	37.23	25.27^{ab}	16.88^{b}	3.93^{c}	8.75^{a}	58.66^{abc}
F–test	ns	**	**	**	**	**

L* = lightness, a* = redness, b* = yellowness, TSS = Total soluble solids, DPPH = radical scavenging assay diphenyl–picrylhydrazyl.
ns, *, ** = non–significant, significant and highly significant differences, respectively.

Table 2. Fruit color index, TSS, lycopene and DPPH of tomato varieties under 2 environments.

Env.	Variety	Fruit color index			TSS	Lycopene	DPPH
		L*	a*	b*	(°brix)	(mg/100 g FW)	(µM TE/100g FW)
E1	*Cherry tomato*						
	Sweet Cherry 154	31.89	21.60^{cde}	12.62^{efgh}	6.06^{b}	8.25^{c}	74.58^{a}
	Sweet Girl	30.37	18.60^{ef}	10.06^{ghi}	7.13^{a}	10.39^{b}	61.10^{cd}
	Sweet Boy	41.64	10.86^{hi}	20.09^{ab}	7.80^{a}	0.46^{f}	76.36^{a}
	Non–cherry tomato						
	Petchchomphu F1	39.97	19.94^{ef}	10.79^{ghi}	3.53^{d}	5.70^{d}	63.83^{bc}
	Sida Namkhem	42.50	26.67^{abc}	12.60^{efgh}	4.06^{cd}	9.65^{bc}	67.41^{b}
	Petch Rung	36.14	25.34^{abcd}	11.44^{efg}	4.00^{cd}	8.51^{c}	46.03^{g}

	Sida	42.25	26.48^{abc}	13.21^{fgh}	3.67^{cd}	10.33^{b}	52.21^{ef}
	Loog Too	33.64	28.88^{a}	14.40^{def}	4.06^{cd}	12.22^{a}	48.84^{fg}

Table 2. Fruit color index, TSS, lycopene and DPPH of tomato varieties under 2 environments. (continue)

Env.	Variety	Fruit color index			TSS	Lycopene	DPPH
		L*	a*	b*	(°brix)	(mg/100 g FW)	(µM TE/100g FW)
E1	Ranger	35.71	25.34^{abcd}	15.72^{cde}	4.00^{cd}	13.11^{a}	60.95^{cd}
	Cherry tomato						
	Sweet Cherry 154	53.39	21.60^{bcde}	16.68^{cd}	4.57^{c}	4.76^{d}	55.65^{de}
	Sweet Girl	36.20	20.98^{def}	14.07^{def}	5.67^{b}	4.68^{d}	57.42^{de}
	Sweet Boy	44.47	7.52^{i}	22.44^{a}	5.83^{b}	0.60^{f}	57.55^{de}
	Non–Cherry tomato						
E2	Petchchomphu F1	41.12	13.24^{gh}	9.65^{hi}	4.00^{cd}	4.57^{d}	55.76^{de}
	Sida Namkhem	46.53	15.88^{fg}	10.66^{ghi}	3.67^{cd}	4.03^{de}	56.65^{de}
	Petch Rung	42.69	18.82^{ef}	12.58^{efgh}	4.16^{d}	4.62^{d}	56.63^{de}
	Sida	39.81	13.25^{gh}	8.05^{i}	3.33^{cd}	2.51^{e}	56.36^{de}
	Loog Too	36.71	27.27^{ab}	16.77^{cd}	4.33^{cd}	5.83^{d}	55.97^{de}
	Ranger	38.76	25.20^{abcd}	18.04^{bc}	3.87^{cd}	4.38^{d}	56.35^{de}
	F–test	ns	*	**	**	**	**

L* = lightness, a* = redness, b* = yellowness, TSS = Total soluble solids, DPPH = radical scavenging assay diphenyl–picrylhydrazyl.

ns, *, ** = non–significant, significant and highly significant differences, respectively.

[1]Means in the same columns with the same letters are not significant differences at P<0.05

Table 3. Correlation coefficient between quality and antioxidants of cherry tomato.

Traits	Lycopene	TSS	L*	a*	b*
DPPH	0.020	0.633*	-0.346	-0.076	-0.058
Lycopene		-0.021	-0.624	0.713*	-0.960**
TSS			-0.543	-0.474	-0.037
L*				-0.149	0.676*
a*					-0.774*

*, ** significant differences at p<0.05 and 0.01, respectively.

Table 4. Correlation coefficient between quality and antioxidants of cherry tomato.

Traits	Lycopene	TSS	L*	a*	b*
DPPH	-0.168	-0.087	0.356	-0.210	-0.068
Lycopene		0.346	-0.504	0.759**	0.392
TSS			-0.348	0.571	0.572
L*				-0.572	-0.448
a*					0.763**

*, ** significant differences at p<0.05 and 0.01, respectively.

DISCUSSION

This study was undertaken to investigated effects of environments and varieties on fruit quality and antioxidants in cherry and non–cherry tomatoes.

From the results, fruit color index including brightness (L*) and yellowness (b*) were not different between environments, but b*value was different among varieties. Redness (a*) value was different between environments and between varieties. Cherry tomato var. Sweet Boy which had yellow fruit color had the highest values of b* value. Non–cherry tomato varieties (Petchchomphu F1, Sida and Sida Namkhem), which have pink color (Nochai and Pongjanta, 2013), had low a* value. In addition, Loog Too and Ranger varieties had the highest redness (a* value) in both environments. TSS of all varieties under E1 condition were higher than under E2 condition. Two varieties namely Sweet Boy and Sweet Girl were found to have high TSS under high temperature (E2) compared to other varieties. High temperature with low humidity in E2 condition reduced TSS, lycopene and antioxidant activity. The results are in agreement with Islam (2011) who reported that content of lutein and carotenoids decreased, and the ratio between various pigments in tomato also changed with high temperature. Generally, the optimum temperature for tomato production is 21–25°C with average temperature >18–27°C (Haque et al., 1999; Araki et al., 2000). The temperature higher than 35°C decreased photosynthesis, transpiration rate in reproductive state, leaf area, plant growth, dry weight, fruit set and delay the development of normal fruit colors (Abdelmageeda et al., 2003; Sato et al., 2006). In addition, high temperature (>38°C) condition could inhibit lycopene production, TSS, carotenoid accumulation and antioxidant activity in tomato (Islam, 2011; Shi and Maguer, 2000; Lokesha et al., 2019). Photosynthetic rates of all tomato genotypes decreased significantly with high temperature (32°C) and the synthesis of chlorophyll content is blocked because of high temperature. Shivashankara et al. (2015) also observed variations among tomato genotypes for fruit qualities at high temperature. Increasing in temperature improved TSS but decreased total sugars, lycopene, and total carotenoids content in 5 genotypes of tomato. The high relative humidity in E1 had higher lycopene accumulation in tomatoes than low relative humidity in E2. Similar result was obtained by Leyva et al. (2013) who reported that tomato grown under 72 %RH greenhouse could produce higher lycopene content than that under 62 %RH greenhouse. However, Xu et al. (2007) reported that tomato grown under low humidity showed higher photosynthesis, chlorophyll content, protein content, rubisco activities, yield and fruit quality than those grown under high humidity. Leyva et al. (2013) suggested that fogging system treatment's decline in maximum vapor pressure deficit, increase in fruit weight and low radiation and temperature may exert a positive effect on lycopene accumulation. Based on these results, non–cherry tomatoes had higher lycopene than cherry varieties across two environments. This result agrees with the research of Bhandari et al. (2016) who also found that cherry tomatoes had lower lycopene content than other groups of tomato. Among non-cherry tomato, the highest lycopene content in both environments was found in Loog Too and Ranger varieties. There was no correlation between lycopene content and anti-oxidant activity (DPPH assay). However, some researchers found negative correlation (Martinez–Valverde et al., 2002) and slightly positive correlation between lycopene content and antioxidant activity (Bhandari et al., 2016). Antioxidant activity had high correlation with total phenolic content but not with lycopene content. There was significantly correlated between lycopene content and fruit color index (a* value) in both cherry and non–cherry tomatoes and b* value had positive correlation with lycopene content in non–cherry tomatoes. Similar result was obtained by Riadh et al. (2016) who reported that a* and b* values were positively correlated to lycopene content in tomatoes. Several experiments reported that a* value can be used to estimate total carotenoid and lycopene content (Hanson et al., 2004; Riadh et al. 2016). The results indicated that antioxidant activity and lycopene were influenced by genetic (varieties) and environments. Temperature and relative humidity conditions had shown to be the main determinant of antioxidant content in tomatoes. However, different varieties responded differently to temperature and relative humidity. Cherry tomato var. Sweet Cherry 154 and Sweet Boy recorded the highest antioxidant activity in terms of DPPH radical scavenging ability in E1 condition (low temperature and high humidity). Too high temperature conditions caused the reduction in antioxidant contents in all genotypes.

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