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Original Article

Papaya carotenoids increased in Oxisols soils

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ABSTRACT

The papaya fruit is healthy for humans as it contains high levels of antioxidants and provitamin A due to high lycopene and β-carotenes contents, respectively. The carotenoids were determined from papayas grown in three different locations—Kamphaeng Saen (KS), Sisaket (SK), and Tha Mai (TM)—and also the study investigated whether the Oxisols soil was capable of increasing the carotenoids content in the papaya fruit. The lycopene, β-carotene and β-cryptoxanthin contents were determined from four different ripening stages (mature green to fully ripe). Concomitantly, the transcript levels of five genes involved in carotenoids biosynthesis—phytoene desaturase (*PDS*), carotene desaturase (*ZDS*), lycopene-β-cyclase (*LCY-B1* and *LCY-B2*), and β-carotene hydroxylase (*B-CHX*)—were investigated. Papayas grown at TM had the highest lycopene, which was supported by the high expression levels of *PDS*, *ZDS* and *B-CHX* and the lower expression levels of the two *LCY-B* genes; however the locations did not affect the fruit quality. The 'Plak Mai Lai' papaya was further investigated by being grown in one location but on two different soil types (Oxisols and Ultisols), to compare their carotenoids contents. Higher carotenoid contents were detected in the papaya grown in the Oxisols.

Introduction

Papaya (*Carica papaya* L.) is one of the world most important tropical fruits, serving both the fresh and canning fruit markets due to its firm texture, sweet taste and appealing colors (Food and Agriculture Organization of the United Nations, 2000). Papaya is also a highly recommended healthy food rich in antioxidants and provitamin A (World Health Organization, 2009). 'Khaek Dam' and 'Plak Mai Lai' are the most popular cultivars in Thailand for fresh fruit consumption due to their high yield, firm, red flesh, preferable flavor and odor (Fuggate et al., 2010).

The main carotenoids in the red-fleshed papaya that interest health-conscious people are lycopene, β-carotene and β-cryptoxanthin; the lycopene content in papaya, found only in the red flesh, varies in the range 1.35–4.31 mg/100 g fresh weight (FW) due to papaya genotypes and geographical locations (Wall, 2006; Schweiggert et al., 2012). Among the red-fleshed genotypes, 'Tailandia', 'Industrial 10G', 'Industrial 10P' and 'Pococi' are distinctively high in carotenoid contents (Kimura et al., 1991; Schweiggert et al., 2011, 2012). Papaya grown in different geographical locations has different carotenoid contents, which has been reported to be due to different climate factors (Shewfelt, 1990; Yadava et al., 1990; Kimura et al., 1991; Almeida et al., 2003; Crane, 2005; Wall, 2006). Brazilian papaya obtained from northeast Brazil (warm climate) had higher carotenoids than that from the southeast (moderate climate) region (Kimura et al., 1991). However, limited data exist on the carotenoids contents of papaya fruits in relation to soil type.

Hawaii and Thailand have tropical climates and have some similarities in geographical and climatic conditions. For example, 'Sunrise' is a popular Hawaiian red-fleshed papaya and Wall (2006) identified carotenoid variations of the 'Sunrise' grown in different plantations. The carotenoid contents of 'Sunrise' papaya harvested from Molloaa were higher than those from Kapoho and the Molloaa and Kapoho plantations had different soil types—Oxisols and Histosols, respectively (Uehara and Ikawa, 2000). Oxisols are also present in Thailand (Bunsompobpan, 1972; Tawornpruek, 2005; Trakoonyingcharoen, 2005; Jaroenchasri et al., 2007). Therefore, it

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was of interest to study whether location and Oxisols could increase the carotenoids content in papaya.

'Khaek Dam Sisaket' (KDS) and 'Plak Mai Lai' (PML), the most popular papaya cultivars of Thailand, were selected for the study. Three locations were specifically chosen for the comparison study of carotenoids content because of their geographical differences and soil types. Kamphaeng Saen (KS) is located in central Thailand, Sisaket (SK) is in the northeast and Tha Mai (TM) is in the east. The soil types of the three locations are Alfisols, Ultisols and Oxisols, respectively. In addition, two soil types, Oxisols and Ultisols, within the same region of TM were investigated for their potential to increase the carotenoids content in papaya fruit.

Materials and methods

Papaya cultivars and growing locations

Two red-fleshed papaya cultivars, 'Khaek Dam Srisaket' (KDS) and 'Plak Mai Lai' (PML), were grown at three locations in Thailand: (1) Kasetsart University, Kamphaeng Saen campus, Nakhon Pathom (KS; 14°03′07.58″N; 99°97′46.11″E); (2) Sisaket Horticultural Crop Research Center, Sisaket (SK; 15°10′85.65″N; 10°42′84.83″E); and (3) Tha Mai district, Chanthaburi (TM), where two plantations were chosen 66 km apart, one having Oxisols and the other having Ultisols soil types (12°61′49.58″N; 102°05′34.58″E and 13°07′61.46″N; 101°95′15.27″E, respectively). The papayas grown at different locations were from the same seed stock of each cultivar. Average temperatures, evaporation, annual rainfall and harvesting time are shown in Table 1. Both cultivars grown at the KS and SK sites were harvested in December 2011, while those grown in TM were harvested in March 2012. The physical and chemical properties of the Alfisols, Ultisols and Oxisols at KS, SK and TM are described in Table 2.

Fruit sample preparation

Twelve fruits of each cultivar were harvested at four ripening stages—mature green (MG; full green and no color developed), 25%

Table 2
Physical and chemical properties of Alfisols, Ultisols and Oxisols at Kamphaeng Saen (KS), Sisaket (SK) and Tha Mai (TM) study sites.

	Location		
	KS[a]	SK[b]	TM[c]
Latitude	14.030758	15.108565	12.614958
Longitude	99.974611	104.284183	102.053458
Order[1]	Alfisols	Ultisols	Oxisols
Soil series[1]	Kamphaeng Saen	Satuek	Tha Mai
Soil characteristic[2]			
pH (H_20)	7.1	4.8	5.1
pH (KCl)	6.4	4.0	4.6
BS (%)	89	56	9
CEC (cmol/kg) (NH_4OAc)	15	1	11
OM (g/kg)	10	7	45
Available P (mg/kg)	56	18	99
Available K (mg/kg)	185	37	23
Texture	loam	loam	clay
Sand (g/kg)	480	568	237
Silt (g/kg)	340	241	391
Clay (g/kg)	180	190	372

CEC = cation exchange capacity; OM = organic matter.
[1,2]The Land Development Department, n.d.b.
[a] Ratneetoo, 1995; Jeimjirashat, 1999.
[b] Yodchompoo, 2010.
[c] Jaroenchasri et al., 2007.

Table 1
Climatic data at Kamphaeng Saen (KS), Sisaket (SK) and Tha Mai (TM) locations during plant growth, fruit set to ripe (Meteorological Department, 2014).

Location	Year	Month	Temperature (°C)	Rainfall (mm)	Evaporation (mm)
KS	2012	August	28.0	59.3	4.4
		September	27.6	485.5	4.2
		October	27.9	131.4	3.8
		November	27.6	114.2	3.2
		December	26.8	0.0	3.4
		Average (5 mth[a])	27.5	158.1	3.8
		Average (4 mth[b])	27.6	182.8	3.7
SK	2012	August	27.9	355.8	4.2
		September	27.7	181.2	3.6
		October	27.8	30.3	3.9
		November	27.5	39.5	3.7
		December	26.1	0.0	4.0
		Average (5 mth[a])	27.3	121.4	3.9
		Average (4 mth[b])	27.4	62.8	3.8
TM	2012	November	24.4	204.4	3.6
		December	21.5	0.0	4.2
	2013	January	23.0	66.8	4.1
		February	28.3	43.7	4.0
		March	29.0	61.2	5.0
		April	29.2	223.8	4.3
		May	29.4	140.8	4.4
		June	28.1	562.3	3.9
		July	27.3	1035.4	2.8
		Average (5 mth[c])	26.8	75.2	4.2
		Average (4 mth[d])	25.8	42.9	4.3
		Average (4 mth[e])	29.0	117.4	4.4
		Average (4 mth[f])	28.5	490.6	3.9

[a] Weather conditions 5 mth before harvest in December 2012 of KDS cultivar.
[b] Weather conditions 4 mth before harvest in December 2012 of PML cultivar.
[c] Weather conditions 5 mth before harvest in March 2013 of KDS cultivar.
[d] Weather conditions 4 mth before harvest in March 2013 of PML cultivar.
[e] Weather conditions 4 mth before harvest in May 2013 of PML cultivar.
[f] Weather conditions 4 mth before harvest in July 2013 of PML cultivar.