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An Analysis on Organic Acids Contents in Ripe Fruits of Fifteen Mao Luang (*Antidesma bunius*) Cultivars, Harvested From Dipterocarp Forest of Phupan Valley in Northeast Thailand

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Abstract: This experiment was carried out in the rainy season (May-October) of the 2006 at the Department of Biotechnology, Faculty of Technology, Mahasarakham University, Mahasarakham 44000, Thailand to analyse organic acids contents in ripe fruits of fifteen Mao Luang cultivars harvested from dipterocarp forest, Phupan Valley, Sakon Nakhon, Northeast Thailand. The experiment was laid in a Completely Randomised Design (CRD) with four replications. The fifteen Mao Luang cultivars were used as treatments. The results showed that there were two groups of organic acids contents in ripe fruits of Mao Luang cultivars i.e., major and minor. The major group of organic acids includes: tartaric acid (7.97-12.16 mg g^{-1} of fresh weight), ascorbic acid (10.01-16.55 mg g^{-1} of fresh weight), citric acid (4.44-11.73 mg g^{-1} of fresh weight) and benzoic acid (8.13-17.43 mg g^{-1} of fresh weight) and the minor group includes malic acid (3.05-4.52 mg g^{-1} of fresh weight), lactic acid (1.12-4.09 mg g^{-1} of fresh weight), oxalic acid (1.00-1.45 mg g^{-1} of fresh weight) and acetic acid (0.19-0.69 mg g^{-1} of fresh weight). Khumlhai cultivar gave the highest amount of ascorbic acid followed by Lompat, Phuchong, Sangkrow 2 and Maelookdog cultivars. Sangkrow 2 and Phuchong cultivars gave the highest ratio between tartaric and malic acids. Total soluble solid content (TSS%) was highest with Sangkrow 5 cultivar, whilst Total Organic Acids (TOA) was highest with Phuchong cultivar and ratio between TSS:TOA was highest with Sangkrow 2 cultivar. Juice % was highest with both Sangkrow 2 and 3 cultivars, whilst Fapratan and Lompat cultivars ranked the second.

Key words: *Antidesma bunius*, Mao Luang, RP-HPLC, fruit quality, organic acids

INTRODUCTION

In an article on Mao Luang cultivars (*Antidesma bunius*) being published recently by Butkhup and Samappito (2008), the results of the research showed that this crop plant is a kind of medicinal plants where many villagers in Northeast Thailand use juices of ripe fruits to heal their health problems on diabetes, dysentery, indigestion and constipation. The research also revealed that Mao Luang fruits contained some enormous amounts of flavonoids chemical compounds, i.e., catechin, procyanidin B1 and procyanidin B2. They further stated that Mao Luang ripe fruits have been used as raw materials for making a tasty jelly jam, juices, juice concentrate and even making a kind of alcoholic wines. This crop plant is naturally distributed throughout Southeast Asia (Roger, 2004). In Thailand it is naturally grown in many dipterocarp forests, particularly in the northeastern region. The plants normally produce fruits in the early rainy season and ripe in late rainy season (May-October). Nowadays, the people in Northeast Thailand have paid more attention to this crop plant since they found that many industrial products have been made from ripe fruits of Mao Luang cultivars so the cultivation of this crop plant has its significant impact for the Thai economy. In making some industrial products, fruit quality is one of many criteria to be considered, e.g., organic acids contents in fruits, fruit chemical compounds, type of sugar contents, pigment and many others are the essential properties that enable the ripe fruits to provide tasty products or even outstanding flavour where such properties have played a major role in improving quality of the products (Ryan and Dupont, 1973; Coppola and Starr, 1986; Fuleki *et al*., 1993). The high amount of acid contents in ripe fruits may not only influence palatability and flavour of the products but it may affect the suitability for specific uses, e.g., with the case of wine making (Romero and Munoz, 1993). It is commonly known that different types of fruits contained different amounts of organic acids. Thus some of the edible fruits are

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used extensively as food acidulates in manufacturing beverages and drinking juices, where some organic acids in ripe fruits may influence sensory properties of its derived products, even though they may be considered as minor components found in fruits when it presents in combination with sugars then they could possibly be an important essence attributed to sensory quality of raw and processed fruits (Wang *et al*., 1993). It has been advocated that some principal acids in ripe fruits could be used to enhance beverage flavours such as citric, malic, oxalic, ascorbic and tartaric acids (Shui and Leong, 2002). Amongst different kinds of edible ripe fruits, they may contain some major types of acids such as citric and malic and some fruits may contain some trace amounts of tartaric, benzoic, oxalic and succinic acids (Kale and Adsule, 1995).

With some industrial products, it is commonly recognized that citric acid is widely used, whilst malic, lactic, oxalic, tartaric, ascorbic, benzoic and acetic acids are normally used for making fruit-flavored in some soft drinks whereas benzoic acid may be used as a preservative in fruit drinks and juices because the pH imparted by natural and added acids may not sufficient to ensure long-term stability of the products against microbial activities. The content of organic acids in fruits not only influences its flavours but also affects its stability, nutritive value, acceptability and quality maintenance. It has been advocated that an increase in lactic and acetic acid contents of the products could avoid bacterial spoilage (Shui and Leong, 2002). The organic acids could provide an authenticity of fruit materials for making juices and beverages (Camara *et al*., 1994). Some information on organic acid levels and ratios among them in fruits could possibly be useful in determining the percentage of juice content and even with other important features (Coppola and Starr, 1986), since each fruit has a unique pattern of organic acids (Wrolstad, 1981). The amount of acids in fruits may be used as an index in identifying fruit maturity stages and it could possibly be one of the major analytical measurements on flavour quality (Fellers, 1991) and it may be used as indicators in determining its full ripening age for harvesting (Palmer and List, 1973). In addition, it may also be useful for the determinations of bacterial activity (Evans *et al*., 1983; Blanco *et al*., 1996). At present, it seems more likely that available data on organic acids of Mao Luang cultivars are limited. Therefore, it may be of tangible value to carry out laboratory work in order to justify types of organic acids contents in ripe Mao Luang fruits including juice percentage, Total Soluble Solid (TSS) content, Total Organic Acids (TOA), TSS:TOA ratio and acidity (pH) in fruits of fifteen Mao Luang cultivars, grown in northeastern region of Thailand. Furthermore, due to economic impact, the cultivation of Mao Luang plant has been widely accepted by growers in the region where this crop provides outstanding medicinal properties and also its tasty drinking quality of juices (Butkhup and Samappito, 2008).

MATERIALS AND METHODS

This investigation was carried out at the Department of Biotechnology, Faculty of Technology, Mahasarakham University, Northeast Thailand to determine different types and amounts of organic acids contents, Total Soluble Solid (TSS), Total Organic Acids (TOA), acidity (pH), juice % and ratios between TSS and TOA in ripe fruits of fifteen Mao Luang cultivars being harvested from dipterocarp forested areas, Phupan Valley, Sakon Nakhon Province, Northeast Thailand during the early rainy season to late rainy season (May-October) of the 2006. An amount of 2 kg of ripe fruits of each cultivar was harvested and kept in a deep fridge (-20±2°C) for further laboratory analysis. The fifteen Mao Luang cultivars include: Sangkrow 2, Fapratan, Sangkrow 1, Maeloogdog, Phuchong, Sangkrow 4, Sangkrow 3, Sangkrow 5, Nonkloy, Lompat, Kumlhai, Sangkrow 8, Sangkrow 7, Chomphupan and Sawang. The experiment was laid in a Completely Randomized Design (CRD) with four replications. Before the commencing of the laboratory analysis, some laboratory preparations were carried out, i.e., a Reverse Phase-High Performance Liquid Chromatography (RP-HPLC) equipment consisted of a Shimadzu (Shimadzu Cooperation Analytical and Measuring Instruments Division Kyoto, Japan), LC-20AD Series pumping system, SIL-10AD Series Auto injector system and SPD-M20A Series Diode Array Detector was set up and used to record online UV spectra of organic acids in each solution of the samples. Standard solutions of each type of acids were prepared and they were used for calibration curves of each individual acid. The data were collected and analysed with a Shimadzu computing system. The column used was an Apollo C_{18} (Alltech) (ø 4.6×250 mm, 5 μm) protected with guard column Inertsil ODS-3 (ϕ 4.0×10 mm, 5 μm). Twenty-microlitre of each sample was analysed. Elution process was carried out using an isocratic elution of the solvent, i.e., 25 mM phosphate buffer (pH 2.5) at a flow rate of 0.8 mL min^{-1} and a column temperature of 40°C were used. The UV-Vis spectra were recorded from 190 to 400 nm. The most suitable wavelength to be recorded was found at a wavelength of 254 nm. The work includes the computation on retention times against authentic standards being identified then quantification was carried out by the integration of the peak reading with the use of an external standard method. Organic acids were extracted with a modification method described by Kafkas *et al.* (2005), i.e., the fruit samples of 5 g each were extracted in a 2% (v/v) aqueous meta-phosphoric acid under room temperature for 30 min where a shaker was used. Each sample of each extracted acid was filtered through with a filter paper of 0.45 μm membrane filter (Millipore) where an amount of approximately 25 mL was collected and then the samples were ready for RP-HPLC analysis. The attained results were statistically analysed using analysis of variance and Duncan's Multiple Range Test (DMRT) with the use of a computer program namely SPSS Version 11.01 (SPSS, 2001).

RESULTS

Standard chromatogram profiles of organic acids, Sangkrow 2 and Fapratan: With the results on RP-HPLC chromatogram of eight-organic acid standards, the results revealed that the reading curve of malic acid was the highest whilst both citric and benzoic acids were the lowest (Fig. 1A). For the results on organic acids contents in ripe fruits of Sangkrow 2 (Fig. 1B) and Fapratan (Fig. 1C), their chromatogram profiles showed that tartaric acid was the highest followed by citric acid, whilst the rest were much lower. The patterns of acids of both cultivars were similar.

The results on a chromatogram profile of organic acids of authentic standards showed that values of retention time of the eight organic acids were 3.532, 4.271, 5.608, 6.289, 7.091, 7.708 and 10.524 min for oxalic, tartaric, malic, ascorbic, lactic, acetic and citric acids, respectively (Table 1). Correlation coefficient (R^2) values ranged from 0.9994 to 0.9999 for ascorbic and acetic acids, respectively.

Organic acids in ripe fruits of fifteen Mao Luang cultivars: It was found that the ripe fruits of fifteen Mao Luang cultivars possessed eight different kinds of organic acids, i.e., (1) tartaric, (2) ascorbic, (3) citric, (4) benzoic, (5) malic, (6) lactic, (7) oxalic and (8) acetic. Due to the differences in available amounts, the organic acids could be categorized into two groups, i.e., major and minor. The major group includes numbers 1 to 4, whilst the minor group includes numbers 5 to 8. For the results of individual organic acid, the results showed that oxalic acid contents in Mao Luang ripe fruits ranged from 1.00 to 1.46 mg g^{-1} of fresh weight for Maelookdog and Sangkrow 5, respectively where Sangkrow 5 ranked the highest followed by Sangkrow 8 and Sawang, whilst the rest were much lower than these three cultivars (Table 2).

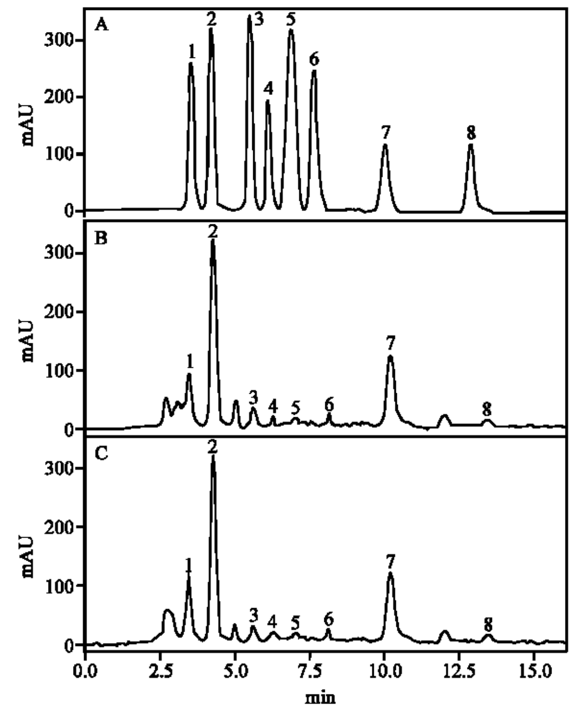

Fig. 1: RP-HPLC chromatogram of eight-organic acid standards (A): 1 = oxalic acid; 2 = tartaric acid; 3 = malic acid; 4 = ascorbic acid; 5 = lactic acid; 6 = acetic acid; 7 = citric acid and 8 = benzoic acid, whilst chromatogram profiles B and C represent organic acids of Sankrow 2 and Fapratan cultivars, respectively

Table 1: RP-HPLC calibration curves of eight organic acids, retention time and correlation coefficients of eight kinds of chemicals being used in the analysis of eight organic acids of fifteen Mao Luang cultivars, grown under natural dipterocarp forest in Northeast Thailand

Organic acids	Retention time (min)	Calibration curves	Correlation coefficient (R^2)
Oxalic	3.532	$Y = 1\times10^7X-1\times10^6$	0.9999
Tartaric	4.271	$Y = 3\times10^6X-1\times10^6$	0.9998
Malic	5.608	$Y = 2\times10^6X$ 736670	0.9995
Ascorbic	6.289	Y = 330994X-323557	0.9994
Lactic	7.091	$Y = 1\times10^6X-116769$	0.9998
Acetic	7.708	Y = 894452X-17646	0.9999
Citric	10.524	$Y = 2\times10^6X-214034$	0.9998
Benzoic	13.010	Y = 141364X-110271	1.0000

The differences were large and statistically significant. Tartaric acid contents ranged from 7.98 to 12.18 mg g^{-1} of fresh weight for Kumlhai and Sangkrow 8, respectively. The differences were large and statistically significant. With malic acid contents, the results revealed that malic acids values ranged from 3.07 to 4.53 mg g^{-1} of fresh weight for Sangkrow 4 and Sangkrow 2, respectively. The differences were large and statistically significant. For ascorbic acid contents, the amounts ranged from 10.04 to

Table 2: Mean values of eight organic acids contents in ripe fruits of fifteen Mao Luang cultivars, grown under natural dipterocarp forest of Phupan Valley, Sakon Nakhon Province, Northeast Thailand

Cultivars	Organic acids (mg g^{-1} of fresh weight) Oxalic	Tartaric	Malic	Ascorbic	Lactic	Acetic	Citric	Benzoic	TOA	Tataric:Malic (Ratio)
Sangkrow 2	1.27c	9.24gh	3.07g	13.99d	1.47ef	0.22cd	5.77f	8.15j	43.17g	3.01a
Fapratan	1.01d	9.56fg	3.44f	11.98i	1.68cde	0.71b	5.31g	9.80i	43.48g	2.78bc
Sangkrow 1	1.01d	10.23def	4.17bc	12.55h	1.54de	0.20d	7.83c	9.71i	44.70g	2.45efg
Maelookdog	1.00d	11.16bc	3.96cd	13.68e	-	0.26cd	6.38e	10.43g	48.30ef	2.82ab
Phuchong	1.01d	11.80ab	3.91e	14.52c	4.11a	2.71a	5.78f	15.20b	59.65a	3.01a
Sangkrow 4	1.01d	10.16def	4.53a	12.19i	3.13b	0.34cd	11.75a	10.51g	47.66f	2.24h
Sangkrow 3	1.00d	8.73hi	3.94de	10.04k	1.28f	0.23cd	5.25g	10.41g	47.36f	2.22h
Sangkrow 5	1.46a	11.55abc	4.14bcd	13.56ef	1.86c	0.34cd	5.80f	14.85c	52.99c	2.79bc
Lompat	1.01d	9.15gh	3.97cde	15.29b	1.70cd	-	8.25b	10.03h	46.93f	2.30gh
Nonkloy	1.02d	11.64abc	4.45a	12.35h	1.52de	0.23cd	4.46h	11.63e	51.08d	2.62cde
Sangkrow 8	1.37b	12.18a	4.43a	13.75e	1.67cde	0.37c	5.70f	14.76c	52.99c	2.74bc
Kumlhai	1.02d	7.98i	4.43a	16.56a	1.68cde	0.27cd	6.89d	15.08b	52.74c	1.80i
Chomphupan	1.02d	9.78efg	3.88e	10.44j	1.15f	0.24cd	6.88d	10.87f	44.26g	2.52def
Sangkrow 7	1.29bc	10.94cd	4.07cde	13.19g	1.69cd	0.25cd	6.45e	17.45a	55.75b	2.69bcd
Sawang	1.33b	10.32de	4.34ab	13.36fg	1.58de	-	6.45e	11.97d	49.33e	2.38fgh
Maximum	1.46	12.18	4.53	16.56	4.11	2.71	11.75	17.45	59.65	3.01
Minimum	1.00	7.98	3.07	10.04	1.15	0.20	8.25	8.15	43.17	1.80
Mean	1.12	10.30	4.05	13.16	1.73	0.42	6.51	12.05	49.36	2.56
CV (%)	14.28	11.84	9.62	12.61	5.03	9.52	26.57	22.07	9.56	12.89

Letter(s) in each column indicate least significant differences of Duncan's Multiple Range Test (DMRT) at probability (p) of 0.05, TOA = Total Organic Acids, CV = Coefficient of Variation (%)

Table 3: Mean values of total soluble solid (TSS %), ratios between total soluble solid (TSS) and total organic acids (TOA), juice % and pH values of fifteen Mao Luang ripe fruits, grown under natural dipterocarp forest of Phupan Valley, Sakon Nakhon Province, Northeast Thailand

Cultivars	Components in ripe fruits TSS (%)	TSS:TOA	Juice (%)	pH
Sangkrow 2	14.80c	0.343a	66.97a	3.28fg
Fapratan	14.10d	0.324b	64.38b	3.47b-f
Sangkrow 1	11.85ef	0.270g	61.19e	3.67b
Maelookdog	14.20d	0.294e	59.81f	3.34efg
Phuchong	14.80c	0.248j	55.10j	3.45c-f
Sangkrow 4	12.35e	0.259h	58.12g	3.17g
Sangkrow 3	12.00e	0.253i	67.21a	3.52b-e
Sangkrow 5	16.50a	0.311d	55.02j	3.64bc
Lompat	12.25e	0.261gh	64.42b	3.54b-e
Nonkloy	15.80b	0.309d	58.51g	4.01a
Sangkrow 8	14.80c	0.279f	56.60i	3.62bcd
Kumlhai	11.30f	0.214k	63.19c	3.44c-f
Chomphupan	14.10d	0.319c	57.10h	3.57bcd
Sangkrow 7	14.00d	0.251ij	60.97e	3.56bcd
Sawang	14.00d	0.284f	62.38d	3.42def
Maximum	16.50	0.343	67.21	4.01
Minimum	11.30	0.214	55.02	3.17
Mean	13.90	0.279	61.12	3.59
CV (%)	10.66	0.123	6.47	5.41

Letter(s) in each column indicate least significant differences of Duncan's Multiple Range Test (DMRT) at probability (p) of 0.05. TSS = Total Soluble Solid, TOA = Total Organic Acids (oxalic, tartaric, malic, ascorbic, lactic, acetic, citric and benzoic acids), CV = Coefficient of Variation (%)

16.56 mg g^{-1} of fresh weight for Kumlhai and Sangkrow 3, respectively. The differences were large and statistically significant. With lactic acids, the values ranged from 1.15 to 4.11 mg g^{-1} of fresh weight for Chomphupan and Phuchong, respectively. The differences were large and statistically significant. For acetic acids, the results showed that acetic acid values ranged from 0.20 to 2.71 mg g^{-1} of fresh weight for Sangkrow 1 and Phuchong, respectively. The differences were large and statistically significant. With citric acids in ripe fruits of Mao Luang, the results showed that citric acid values ranged from 4.46 to 11.75 mg g^{-1} of fresh weight for Nongkloy and Sangkrow 4, respectively. The differences were large and statistically significant. For benzoic acids, mean values of fifteen Mao Luang ranged from 8.15 to 17.45 mg g^{-1} of fresh weight for Sangkrow 2 and Sangkrow 4, respectively. The differences were large and statistically significant. With amounts of Total Organic Acids (TOA) of each cultivar, the results showed that mean values of total orgamic acids ranged from 43.17 to 59.65 mg g^{-1} of fresh weight for Sangkrow 2 and Phuchong, respectively. The differences were large and statistically significant. For tartaric and malic ratios, the results showed that ratio between tartaric and malic acids of fifteen Mao Luang fruits ranged from 1.80 to 3.01 mg g^{-1} of fresh weight for Kumlhai and Phuchong, respectively. The differences were large and statistically significant. With mean values of all orgamic acids, the results showed that mean values ranged from 0.42 to 13.16 mg g^{-1} of fresh weight for acetic acid and ascorbic acid, respectively.

Total soluble solid, juice %, pH and ratio between Total Soluble Solid (TSS) and amounts of Total Organic Acids (TOA): The results showed that amount of Total Soluble Solid (TSS) content in ripe fruits of fifteen Mao Luang cultivars ranged from 11.30 to 16.50% for Kumlhai and Sangkrow 5, respectively. The differences were large and statistically significant (Table 3). The results on ratio between total soluble solid content and total organic acid revealed that ratio values ranged from 21.43 to 34.28% for Chumphupan and Sangkrow 2, respectively. The differences were large and statistically significant. With juice %, the results showed that juice % ranged from 55.02 to 67.21 for Sangkrow 5 and Sangkrow 2, respectively. The differences were large and statistically significant. For pH values, the results revealed that mean pH values ranged from 3.17 to 4.01 for Sangkrow 4 and Nonkloy, respectively. The differences were large and statistically significant.

DISCUSSION

From the results of RP-HPLC laboratory analysis, the results showed that there were eight different kinds of organic acids contents found in edible ripe fruits of fifteen Mao Luang cultivars. Due to the available amounts, the organic acids could be categorized into two groups, i.e., major and minor. The major group includes tartaric, ascorbic, citric, benzoic acids and the minor group includes malic, lactic, oxalic and acetic acids. Therefore, the results showed some tremendous amounts of different organic acids available in ripe fruits of the Mao Luang plants where these organic acids may possess its high palatability characteristics with more or less favourable taste for man or even animals when consume. Apart from the numerous types of organic acids available in ripe fruits, some important amounts of flavonoids, i.e., catechin, procyanidin A and procyanidin B were also found in ripe fruits of Mao Luang cultivars (Butkhup and Samappito, 2008). The different organic acids together with flavonoids found in ripe fruits may possess medicinal properties for use in man daily life as stated by a number of workers, e.g., Mangiapane *et al.* (1992), Teissedre *et al.* (1996), Hertog *et al.* (1997), Knekt *et al.* (1997), Kuulasmaa *et al.* (2000), Rein *et al.* (2000) and Stoclet *et al.* (2004). However, it was found that some of the organic acids were not available in some cultivars, i.e., lactic acid was not found in ripe fruits of Maelookdog and acetic acid was not found in ripe fruits of Lompat and Sawang cultivars. This could possibly be attributable to perhaps genetic treats of the Mao Luang cultivars and it could be possible that the lack of some nutrients available in soil for plant roots to absorb may have some effects on the production of lactic and acetic acids in ripe fruits of Lompat and Sawang cultivars since the release of nutrients in soils depended most on soil pH and parental sources of soil nutrients, which may reflect available amounts in soils (Mengel and Kirkby, 1987; Miller and Donahue, 1990; Suksri, 1999). Thus soil analysis may be needed in order to explain the differences in the amount and type of organic acids contents in edible ripe fruits of Mao Luang cultivars. It may be of interest to provide adequate amounts of both macro and micronutrients to the crop plants at least one month before flowering initiation takes place in order to supply all nutrients needed by the crop plants. Therefore, soil pH should be maintained within a range of 6-6.5 (1:2.5 soil:water by volume) so that most of soil nutrients should be able to release in soil for plant roots and they should be adequately available, hence its annual fruit production and quality of fruits could possibly be significantly improved.

It was found that mean value of ascorbic acid was highest followed by benzoic, tartaric and citric acids with mean values of 13.16, 12.05, 10.30 and 6.51 mg g^{-1} of fresh weight, respectively, whilst the rest were relatively small where the values were lesser than 5 mg g^{-1} of fresh weight. The results indicated that Mao Luang ripe fruits possess a relatively high amount of vitamin C, i.e., ascorbic acid content was plentiful in ripe fruits hence a sour taste could be easily detected. The highest amount of ascorbic acid content was found in fruits of Khumlhai followed by Lompat, Phuchong, Sangkrow 2 and Maelookdog with mean values of 16.56, 15.29, 14.52, 13.99 and 13.68 mg g^{-1} of fresh weight, respectively whilst the rest were much lesser. The results indicated some variations in the amounts of ascorbic acid contents in fruits. This may again be attributable to the differences in genetic traits or perhaps the variation in soil nutrients available for plant roots as discussed earlier. Ripe fruits of Khumlhai and Lompat cultivars gave higher amounts of ascorbic acid contents than those found in fruits of Blackberry genotypes as reported by Kafkas *et al.* (2005), whilst tartaric, malic and citric acids contents were higher than those reported by Soyer *et al.* (2003) where their results derived from fruits of Turkish white grapes. Suksri (1999) stated that in most acidic soils with small available amount of exchangeable potassium and high in the amount of decomposed materials then there is a tendency for plant roots to attain much higher amount of nitrate nitrogen hence taste of most orchard fruits could be soured. This could possibly be a reason for high amount of ascorbic acid content in Mao Luang ripe fruits apart from the differences in genetic traits of the crop plants. Therefore, in terms of ascorbic acid contents in ripe fruits when it comes to cultivation, Khumlhai should be an ideal cultivar followed by Lompat, Phuchong, Sangkrow 2 and Maelookdog, whilst the rest were of secondary importance.

For alcoholic wine making, a high value derived from a ratio between tartaric acid and malic acid in fruits could be an ideal type (Fuleki *et al.*, 1993). With this work it was found that Sangkrow 2 and Phuchong gave the highest (both were similar) followed by Maelookdog, Fapratan, Sangkrow 5, Sangkrow 8 and Sangkrow 7, whilst the rest could possibly be out of place. Thus Sangkrow 2 and Phuchong cultivars should be recommended for cultivation in terms of wine making. The reason for variation in values of ratios between tartaric acid and malic acid may be due to genetic traits and perhaps soil environments may possess some effects as described earlier. It has been advocated that juices and alcoholic wine contained some considerable amounts of lactic and acetic acids could prevent microbial spoilage as reported by Kupina (1984) and Plessisa *et al.* (2004). With this work, it was found that Phuchong cultivar gave highest mean values in both lactic and acetic acids, thus Phuchong may be an ideal cultivar for crop cultivation in terms of food preservation of drinking juices and alcoholic wine, whilst the rest were not comparable.

With Total Soluble Solid (TSS %), the results showed that Sangkrow 5 gave the highest followed by Nonkloy and Sangkrow 2, whilst the rest were much lower yet all of them gave much higher TSS% than those found in fruits of strawberry as reported by Sturma *et al.* (2003) and citrus by Karadenuz (2004) but lower than litchi (Ramma, 2003), white grape (Soyer *et al.*, 2003) and red grape (Orak, 2007). It has been stated that TSS is the function of several factors concerning sugars and organic acids, thus in most cases the higher the better (Sturma *et al.*, 2003). When it comes to ratio between Total Soluble Solid (TSS) and Total Organic Acids (TOA), the results revealed that the value was highest with Sangkrow 2 followed by Fapratan and Chomphupan, whilst the rest were much lower. The results suggested that the high value could possibly be of an important factor due to perhaps high amount of sugars and organic acids contents. Juice percentages were highest with Sangkrow 2 and Sangkrow 3 (both were similar) followed by Fapratan and Lompat (these two cultivars were similar), thus in terms of fresh drinking juices Sangkrow 2 and Sangkrow 3 cultivars should be ideal cultivars for crop cultivation followed by Fapratan and Lompat, whilst the rest may provide a smaller benefit. With pH values, the results indicated that the least acidity in drinking juice was found with Nonkloy followed by Sangkrow 1, Sangkrow 5, Sangkrow 8 and Chomphupan where the rest gave much lower values of acidity level. The results suggested that the high pH value cultivar (Nonkloy) had a higher amount of calcium content than the rest. Therefore, Nonkloy cultivar could be an ideal cultivar for further cultivation in terms of juice calcium content. It may be of interest to analyse the juices of all cultivars for calcium contents in order to justify if the juices of higher pH values could provide higher amounts of calcium contents. Therefore, in terms of crop cultivation, it could be rather difficult to judge which cultivar should be recommended for growers to cultivate but in terms of total organic acids content then Phuchong cultivar should rank the first followed by Sangkrow 7, Sangkrow 8 and Nonkloy, whilst other cultivars could possibly be out of place. If juice % is taken into account then Sangkrow 2 and Sangkrow 3 should rank the first followed by Lompat and Fapratan, whilst other cultivars may not be accounted. Another point to consider is its annual production and branching characteristics that favour high fruit yield. Thus further investigation within several plantations is needed in order to explain the differences in fruit production and the results may be useful for growers to choose, which cultivar is the most appropriate cultivar for further cultivation. In addition, it may be of important value to determine type of sugar contents in ripe fruits since information on this respect is limited.

CONCLUSIONS

From the RP-HPLC laboratory analysis, it was found that edible ripe fruits of fifteen Mao Luang cultivars harvested from Phupan Valley of Sakon Nakhon Province, Northeast Thailand gave eight different kinds of organic acids. The organic acids were categorized according to the available amounts into two groups i.e., major and minor. The major group includes oxalic, tartaric, malic and ascorbic acids, whilst the minor group includes lactic, acetic, citric and benzoic acids. Ascorbic acid content ranked the highest followed by benzoic, tartaric and citric acids, whilst the rest were relatively small. Khumlhai gave the highest amount of ascorbic acid followed by Lompat Phuchong, Sangkrow 2 and Maelookdog, whilst the rest were relatively small. Sangkrow 2 and Phuchong gave the highest ratio between tartaric and malic acids. Total Soluble Solid % (TSS %) were highest with Sangkrow 5 and Total Organic Acids (TOA) was highest with Phuchong whilst ratio between TSS:TOA was highest with Sangkrow 2. Juice % was highest with both Sangkrow 2 and Sangkrow 3, whilst both Fapratan and Lompat cultivars ranked the second.

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