Research article

Quality Comparison of Naturally and Artificially Ripened 'Monthong' Durian (*Durio zibethinus*) Fruits Harvested at Various Maturity Stages

Pannipa Youryon[1] and Suriyan Supapvanich[2]*

[1]*Department of Agricultural Technology, Prince of Chumphon Campus, King Mongkut's Institute of Technology Ladkrabang , Pathio District, Chumphon Province, Thailand*
[2]*Department of Agricultural Education, School of Industrial Education and Technology, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand*

Received: 3 July 2021, Revised: 14 December 2021, Accepted: 28 January 2022

DOI: 10.55003/cast.2022.06.22.002

Keywords

durian;

ethephon;

eating quality;

bioactive compounds

Abstract

The effects of artificial and natural ripening approaches on the quality of 'Monthong' durians harvested at various maturity stages were investigated. The fruits were harvested at the maturity stages of 110 (~ 80% maturity), 115 (~ 85% maturity) and 120 (~ 90% maturity) days after anthesis (DAA) and were then artifically ripened by smearing ethephon on peduncle cut surfaces, or were allowed to naturally ripen at room temperature (28±2°C). The ripening period and quality of the ripened durians were determined and compared with the tree-ripened durians (130 DAA). The fruits harvested at 110, 115 and 120 DAA fruits were naturally ripened on days 9, 6 and 4, respectively, after harvesting. All fruits treated with ethephon had ripened on 3 days. Durians at more mature stages had higher pulp yellowness and carotenoid content while the ripening approach had no influence on both parameters. Pulp firmness of naturally ripened durians was lower than artifically ripened fruits. The starch content of the130 DAA fruits was high and similar to durians harvested at 120 DAA, after ripening. The tree-ripened durians had the highest soluble solids content (SSC) and total sugars contents (TSC). The values of SSC and TSC of naturally ripened fruits were higher than those of artificially ripened fruits. Durians harvested at more maturity had higher antixodant capapcity compared to yourger durians. Natural ripening induced antioxidants more than artifical ripening. In conclusion, artificial ripening hastened the ripening period, and the quality of 120 DAA durians after ripening was close to that of 130 DAA fruit.

*Corresponding author: E-mail: suriyan.su@kmitl.ac.th

1. Introduction

Durian (*Durio zibetfunus*, Murray) is a famous commercial tropical fruit that has its geographical origins in Southeast Asia (Borneo, Sumatra, and Peninsular Malaysia) [1]. It has been claimed as the King of tropical fruits. Durians are mainly produced in Thailand, Malaysia and Indonesia [2]. Recently, Thailand has become the biggest durian producer and exporter to the world market [3]. The demand for durians in both domestic and export markets has continuously increased. The main country importing durians from Thailand is China [4]. The most popular cultivars of Thai durians are 'Monthong' and 'Chanee' [5]. The demand for 'Monthong' fruit in both domestic and export markets is higher than 'Chanee' fruit. The quality of durians depends on maturity stage and postharvest practice. In Thailand, durians are typically harvested at 75-85% maturity whilst in Malaysia and Indonesia, the fruits are left to ripen on the tree [2]. The full maturity of 'Monthong' durians (100% maturity) refers to the stage at which the fruits are ready to fall off the tree, or the days after anthesis (DAA) of the fruits, which is about 130 days [2]. 'Monthong' durian for domestic market is generally harvested at 90% of maturity (120-125 DAA) and for export by shipping, the fruit at 110-115 DAA (75-85% maturity) is harvested [2]. The time to ripeness of the fruit and eating quality depended on fruit maturity. Artificial ripening by brushing the active ingredient of ethephon at a concentration of 48% onto the cut surface of the peduncle is a typical practice in packinghouses to hasten the ripening period and uniformity in ripening of durians [6]. It has been shown that fruit maturity influences quality of fruit after artificial ripening. Cheyglinted [7] reported that 'Chanee' durians harvested at 75% maturity failed to ripen after artificial ripening (ethephon treatment) whilst the fruit at 85 % maturity had good quality after ethephon treatment. Thongkum *et al*. [8] reported that ethephon treatment evidently induced ethylene production of 'Monthong' durians harvested at 112 DAA, and the time to ripeness at 25ºC was 3 days. Moreover, in banana, artificial ripening by immersion into 500 ppm ethrel (ethephon) hastened time to ripeness to 6 days at 20ºC and provided good eating quality and peel color [9]. In avocado, artificial ripening using ethrel and CaC_2 reduced the ripening period by 5 days and the fruit quality after ripening was similar to the naturally ripened fruits [10]. Kunjet *et al*. [11] reported that dry weight, soluble solids, starch and lipid content of durians treated with ethephon did not differ from those of untreated fruit. However, the influence of maturity stages on quality of 'Monthong' durians after commercially artificial ripening compared with on-tree ripened fruit had not been found. Therefore, this work was aimed to compare the quality of 'Monthong' durians harvested at various maturity stages after commercially artificial ripening with the quality of naturally ripened fruits.

2. Materials and Methods

2.1 Plant materials

'Monthong' durians were derived from a commercial orchard at Pathio District, Chumphon province. The average temperature during the fruit development was approximately 33-34ºC, data which was obtained from Chumphon meteorological station. The durians were gathered at the maturity of 110 (~ 80% maturity), 115 (~ 85 % maturity), 120 (~ 90% maturity) and 130 (fruits which were left to ripen on the tree) DAA. The maturity of the durians was screened using DAA and again selected by an expert durian harvester before being delivered to Horticultural Laboratory, Department of Agricultural Technology, Prince of Chumphon's campus, KMITL. The average size of the durians was in the range of 3-4.5 kg per fruit. The fruits were cleaned using air injection and brushing. Ten fruits of each maturity stage were artificially ripened by brushing with 48% (active ingredient) ethephon on the cut-surface of the peduncle at room temperature. Another ten fruits were naturally ripened at room temperature. The time to ripeness of the fruits, that is the time to when the fruit had desirable eating qualities (soft texture and desirable ripe durian smell), was recorded. The arils having similar quality which screened by pulp color and texture of each lodicule in a fruit were sampled. Physicochemical qualities of ripened fruits, such as color, texture, soluble solids content (SSC), total sugars content (TSC), starch content and antioxidants of the fruit pulp were monitored.

2.2 Pulp color measurement

The color of fruit pulp was measured using a Minolta CR-000 colorimeter (Minolta Inc., USA). Three measurements were taken at 3 different parts on the fruit pulp. Lightness (L*) and yellowness (b*) values were recorded.

2.3 Texture measurement

The firmness of durian pulp was measured using a texture analyzer model TA.XT plus C Specification (Stable Micro System, UK). The P/6 cylinder probe was used to measure the pulp texture. The measurement was operated at a probe speed of 1.0 mm s^{-1} to a depth of 5 mm. The firmness was measured in the middle part of the durian aril. The pulp firmness was expressed in Newton per square meter (N m^{-2})

2.4 Total carotenoids assay

A 5 g sample of durian pulp was homogenized with 15 ml of absolute ethanol and then filtered through a Whatman no. 1 filter paper. The cake was rinsed with absolute ethanol until colorless. The volume of filtrate was adjusted to 100 ml with absolute ethanol. Absorbance of the solution was measured at the wavelengths of 645, 663 and 470 nm. Total carotenoid content was calculated using Kirk's equation [12]. The data was expressed as mg per kg fresh weight (mg kg^{-1}).

2.5 Soluble solids content assays

A 5 g sample of durian pulp was homogenized with 10 ml distilled water and then stirred for 1 h at room temperature. The homogenate was centrifuged at the speed of 10,000 x g at room temperature for 15 min. The supernatant was collected and used to determine SSC using a hand-refractometer (Atago, Japan). The data were expressed as % of SSC.

2.6 Total sugars content and total starch content assays

A 10 g sample of durian pulp was homogenized with the solution of 100 ml of distilled water (consisting of 5 ml of 6% Zinc acetate solution and 5 ml of 6% Potassium ferrocyanide solution). The mixture was shaken for 30 min and then filtered using a Whatman filter paper No. 4. The collected solution was used to determine TSC and the precipitate was used to determine total starch content using the method of Association of Official Analytical Chemists [13] and Miller [14]. The amounts of TSC and total starch content were present as gram per kilogram fresh weight (g kg^{-1}).

2.7 Antioxidant determination

A 5 g sample of durian pulp was homogenized with 15 ml of absolute ethanol. The homogenate was centrifuged at 10000 x g for 15 min at room temperature. The supernatant was collected for assay of free radical scavenging activity using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical scavenging activity assay, following the method of Brand-Williams *et al*. [15]. The absorbance at 517 nm was recorded immediately at 0 min (A_0). The reaction was held under dark for 10 min and the absorbance at 517 nm was then recorded (A_{10}). The percentage of DPPH scavenging activity was calculated with the following formula:

$$\text{Free radical scavenging capacity (\%)} = [(A_0 - A_{10})/A_0] \times 100$$

2.8 Ferric reducing antioxidant potential assay

A 5 g sample of durian pulp was homogenized with 60% ethanol and the homogenate was then stirred for 30 min. The sample was centrifuged at 10000 x g for 15 min. The supernatant was collected and used to determine ferric reducing antioxidant potential (FRAP), via the method described by Benzie and Strain [16]. The absorbance at wavelength of 630 nm of the reaction solution was recorded after it had been left at room temperature for 30 min. The collected data was computed using a linear equation of trolox standard curve. FRAP was expressed as mmole trolox equivalents per kilogram (mmol kg^{-1}).

2.9 Statistical analysis

The data are shown as the mean and standard deviation (S.D.) of ten durian fruits. The experiment was designed using Completely Randomized Design (CRD). Analysis of Variance (ANOVA) was used to analyze data and the means compared by DMRT at a significance level of 0.05.

3. Results and Discussion

3.1 Time to ripeness, color attributes and carotenoids content

Time to ripeness, color attributes and carotenoids content of both artificially and naturally ripened durians are shown in Table 1. The time to ripeness of naturally ripened durians was dependent upon fruit maturity. More mature fruits took a shorter period to ripen compared to the younger fruits. The fruits harvested at 120, 115 and 110 DAA naturally ripened on days 4, 6 and 9 after harvest, respectively. The artificial ripening hastened time to ripeness of the fruits which had ripened on day 3 after harvest. In a similar vein, Thongkum and co-workers [8] also reported that durian treated with ethephon ripened 3 days after brushing ethephon on the stem cut surface. Artificial ripening had no impact on pulp lightness. However, fruit maturity had an effect on pulp yellowness. The highest pulp yellowness was found in the tree-ripened durians and it tended to be higher than 115 and 120 DAA fruits after ripening. Pulp yellowness of the 110 DAA fruits after being artificially ripened or naturally ripened was significantly lower than that of other fruits ($P < 0.05$). Both artificial and natural ripening approaches had no effect on pulp yellowness. The change in carotenoids content was positively related to pulp yellowness and fruit maturity. No significant difference in carotenoids content was found between naturally ripened and artificially ripened fruits. The lowest carotenoids content was detected in the fruits harvested at 110 DAA after ripening. No significant differences in carotenoids content of the fruits harvested at 115, 120 and 130 DAA was found after ripening. It is widely recognized that the increase in pulp yellowness of durian at maturity is associated with carotenoid biosynthesis [17]. We found that the pulp yellowness was positively associated with carotenoids content in which the more mature the stage, the higher the pulp yellowness and carotenoids content. The increased pulp yellowness was also related with the reduction of pulp

Table 1 Ripening period, color attributes and carotenoids content of naturally and artificially ripened 'Monthong' durian fruits harvested at various maturity stages compared with the tree-ripened durian fruits

Maturity (DAA)	Ripening approach	Ripening period (d)	Color attributes		Carotenoids
			*L**	*b**	(mg kg^{-1})
130	Tree-ripened durians		85.68±1.12 ^{a}	42.78±1.47 ^{a}	2.27±0.21 ^{a}
110	Natural	9	87.92±1.66 ^{a}	36.17±3.60 ^{b}	1.42±0.11 ^{b}
	Artificial	3	87.00±1.79 ^{a}	37.32±3.71 ^{b}	1.25±0.05^{b}
115	Natural	6	86.09±1.18 ^{a}	39.43±4.30 ^{ab}	1.89±0.26 ^{a}
	Artificial	3	86.19±1.73 ^{a}	39.23±3.03 ^{ab}	1.98±0.15 ^{a}
120	Natural	4	85.92±2.05 ^{a}	39.81±3.85 ^{ab}	1.83±0.40 ^{a}
	Artificial	3	86.26±1.73 ^{a}	39.33±3.03 ^{ab}	2.11±0.15 ^{a}

Values followed by different letters within a column are significantly different at $P < 0.05$.

lightness. This was in agreement with the report of Wisutiamonkul *et al*. [18] who found that the *L** value of both 'Monthong' and 'Chanee' durians declined with maturity increase. They also reported the increments of β-carotene and α-carotene in 'Monthong' durian pulp during ripening. Moreover, Wisutiamonkul *et al*. [19] suggested that the artificial ripening approach did not affect carotenoids content in durians. Therefore, it is concomitant with our result that no significant difference in the carotenoids content of artificially ripened and naturally ripened fruit was found.

3.2 Pulp texture

Figure 1 shows the pulp firmness of durian fruits after artificial and natural ripening. Pulp firmness of the tree-ripened fruits (130 DAA fruits) and all naturally ripened fruits were similar and were significantly lower than that of artificially ripened fruits ($P < 0.05$). The firmness of all artificially ripened fruits was higher than that of all naturally ripened fruits by about 1 N m^{-2}. It is commonly acknowledged that softening or firmness reduction of durian pulp during ripening is associated with the activities of cell wall hydrolases such as polygalacturonase and pectinmethylesterase [20] and expansin genesis [21]. Ethylene is accepted as playing an important role in durian pulp softening by stimulating expansin genesis, resulting in cell wall separation [21], and inducing cell wall hydrolases activities due to the de-polymerization of pectin structure [20]. Palaphon *et al*. [21] suggested that expansin gene expression occurred before the onset of softening in which the peak of the *DzEXP1* gene expression was detected after treating with ethephon for 1 day. Regarding the typical eating quality of durians for Thais, it seems that desirable organoleptic attributes are firm with slightly soft texture (the onset of softening), sweet-starchy taste and mild smell. Therefore, the texture of the fruits in this study were measured when the fruits had just ripened and were suitable for commercial consumption. In this study, the ripened on the tree fruits (130 DAA) were screened by an expert

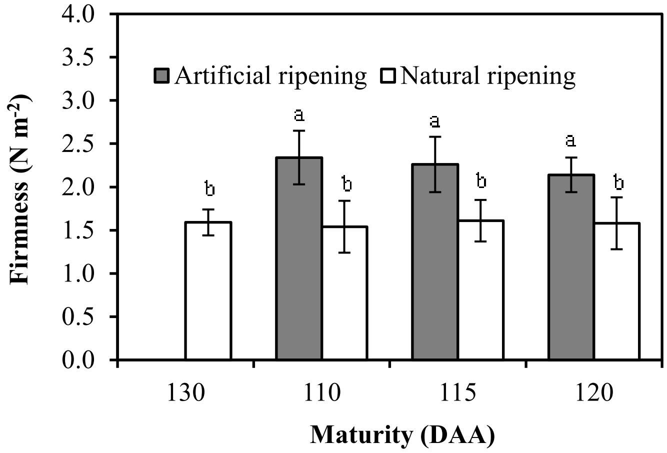

Figure 1. Pulp firmness of the naturally and artificially ripened 'Monthong' durian fruits harvested at various maturity stages. Data represent the mean 10 fruits with vertical bar of S.D. Values with different letters are significantly different at $P < 0.05$.

durian harvester who discerned that the pulp quality, including pulp yellowness and texture, were suitable for consumption. As the results shown in Table 1, artificial ripening hastened the ripening period of the fruits (3 days after smearing ethephon on the stem cut surface) whilst the ripening period of naturally ripened fruits took longer times. Ketsa and Daengkanit [22] reported that pulp firmness of 'Monthong' durian harvested at 123±2 days after full bloom was markedly decreased after 4 days of storage at room temperature, due to the increases of polygalacturonase and pectinmethylesterase activities. Palapol *et al*. [21] reported that pulp firmness of ethephon treated durians after storage for 3 days at ambient temperature was higher than that of the naturally ripened fruits after storage for 5 days. They also suggested that artificial ripening using ethephon slightly hastened durian pulp softening.

3.3 Starch content

Changes in starch content of the durian pulp after artificial and natural ripening are shown in Figure 2. The highest starch content was found in pulp of the 130 DAA fruits. No significant difference in starch content between 130 DAA fruits and 120 DAA fruits after natural or artificial ripening was found. Naturally ripened 110 and 115 DAA fruits had significantly lower starch content than both of the artificially ripened fruits ($P < 0.05$). However, the starch content of the 110 DAA fruits tended to be lower than that of 115, 120 and 130 DAA fruits after ripening. This suggested that the ripening approach had an effect on starch content of the durian fruit harvested at 110 and 115 DAA whereas the fruits harvested at 120 DAA had no difference in starch content between artificially and naturally ripened fruits and the starch content was similar to the fruits left to ripen on the tree. Moreover, the results also revealed that at the onset of ripening, the amount of starch in durians might not play a key role in pulp softening compared to cell wall degradation as described by Ketsa and Daengkanit [20] and Palapol *et al*. [21]. It is widely recognized that starch accumulation in durian pulp increases following maturity increase and then it will decrease during the ripening process due to the conversion of starch to sugars. Durian fruit at the maturity of 110 DAA is recognized as the stage of 80% maturity and the starch accumulation might not be completed when compared to the more

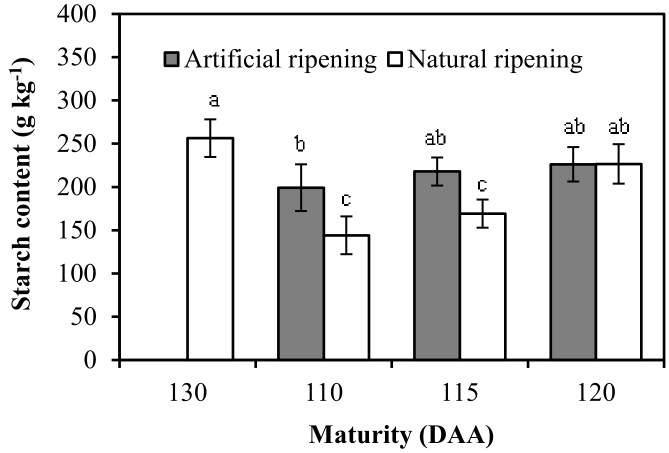

Figure 2. Starch content in pulp of the naturally and artificially ripened 'Monthong' durian fruits harvested at various maturity stages. Data represent the mean 10 fruits with vertical bar of S.D. Values with different letters are significantly different at $P < 0.05$.

mature fruits (85 and 90% maturity stages). Artificial ripening produced higher starch content than natural ripening in the fruit harvested at 110 and115 DAA because the ripening time of naturally ripened fruits was longer by 3 and 2 times, respectively. However, no significant difference in starch content of all artificially ripened fruits was observed. This may suggest that the onset of starch conversion to sugars was just occurring at the stage of ripening. Ketsa and Daengkanit [22] suggested that marked decrease in starch content of durian pulp was positively related to the increase in ripening process.

3.4 Soluble solids and total sugars contents

As the results shown in Figure 3A, the SSC of the 130 DAA fruits was significantly higher than that of other fruits ($P < 0.05$). The SSC of the naturally ripened fruits which were harvested at 110, 115 and 120 DAA was not significantly different. For the fruits harvested at 120 DAA, the SSC of the artificially ripened fruits was similar to that of naturally ripened fruits. For the fruit harvested at 115 DAA, artificial ripening tended to produce lower SCC than naturally ripened fruits. The lowest SSC was found in artificially ripened 110 DAA fruits, and it was significantly lower than that of the naturally ripened fruits ($P < 0.05$). The highest TSC was observed in the tree-ripened fruits, and it was significantly higher than the fruits harvested at 120, 115 and 110 DAA after ripening, respectively ($P < 0.05$) (Figure 3B). The TSC of the naturally and artificially ripened fruits harvested at 120 DAA was not different. The TSC of the naturally ripened fruits harvested at 110 and 115 DAA was significantly higher than that of artificially ripened fruits ($P < 0.05$). The lowest TSC was found in the artificially ripened fruits harvested at 110 DAA. These suggested that the SSC and TSC of the durians are positively dependent on maturity stage. The fruits at the onset of maturity and mature stages had lower SSC and TSC after artificial ripening when compared to natural ripening. We also found that both artificially and naturally ripening approaches had no effect on SSC and TSC in the fruits at 90% maturity stage (120 DAA fruits) after ripening. The increases in SSC and TSC of the durian pulp were negatively related with the amount of starch content as shown in Figure 2. In the similar vein, Ketsa and Daengkanit [22] and Añabesa *et al*. [23] found that the increment

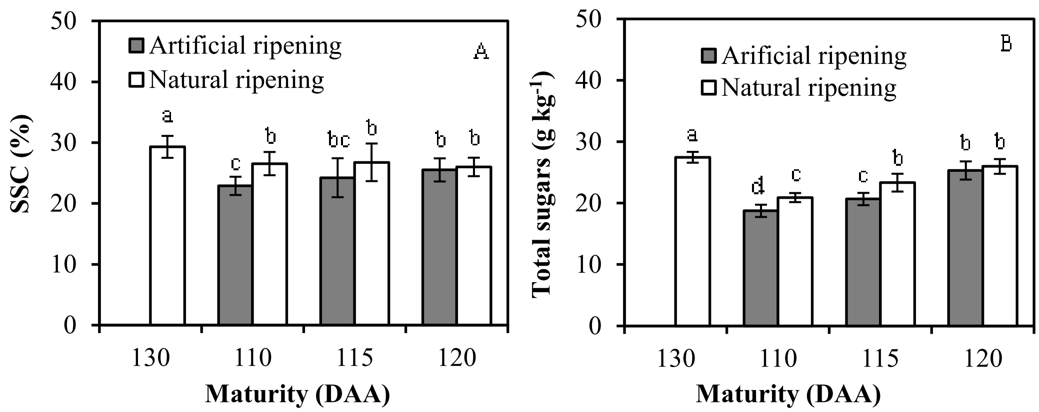

Figure 3. Soluble solids content (SSC) (A) and total sugars content (TSC) (B) of the naturally and artificially ripened 'Monthong' durian fruits. Data represent the mean 10 fruits with vertical bar of S.D. Values with different letters are significantly different at P < 0.05.

of SSC was concomitant with the reduction of starch content and the increased total sugars content in durians during the ripening process.

3.5 Antioxidant activities

Table 2 shows the antioxidant activities of the durian fruits using DPPH free radical scavenging and FRAP assays. It was found that the tree-ripened fruits had the highest levels of both antioxidant activities. However, both antioxidant activities of the tree-ripened fruits were not significantly different from those of both artificially and naturally ripened fruits harvested at 120 DAA. The lowest values of both DPPH free radical scavenging activity and FRAP were found in artificially ripened 110 DAA fruits which were significantly lower than those of the naturally ripened fruits (P < 0.05). Naturally ripened fruits harvested at 115 DAA had DPPH free radical scavenging activity and FRAP that were significantly higher than those of the artificially ripened fruits (P < 0.05). The results indicated that the higher the maturity, the higher the antioxidant activity was detected. Haruenkit *et al*. [24] also reported that increased antioxidants in 'Monthong' durians were positively concomitant with the increase in fruit maturity. In this work, the highest antioxidants were found in overripe fruits followed by ripe, mature and immature fruits, respectively. Our results showed that naturally ripened fruits harvested at 80% maturity (110 DAA fruits) and 85% maturity (115 DAA fruits) had higher antioxidant activities than artificially ripened fruits. A similar result was reported for 'Manjira' mango in which artificial ripening using 150 µl l^{-1} ethephon had a negative effect on the antioxidant activities of the mangoes compared to natural ripening [25]. However, the ripening approach had no impact on antioxidant activities of the tree-ripened fruits. Moreover, the higher FRAP value of naturally ripened fruits might be related to the increased TSC, as the results shown in Figure 3B. It is commonly acknowledged that FRAP reagent can react with reducing group of reducing sugars and the increase in reducing sugars is naturally detected in fruit including durian due to the conversion of starch to sugars [23].

Table 2. Antioxidant activities of naturally and artificially ripened 'Monthong' durian fruits harvested at various maturity stages

Maturity (DAA)	Ripening approach	Antioxidant activity	
		DPPH scavenging activity (%)	**FRAP (mmol kg^{-1})**
130	Tree-ripened durians	9.97±1.92 [a]	236.31±20.50 [a]
110	Artificial	6.60±0.48 [b]	56.42±2.15 [d]
	Natural	7.57±1.08 [ab]	64.97±2.03 [c]
115	Artificial	6.82±0.52 [b]	66.05±1.20 [c]
	Natural	8.68±0.88 [a]	69.70±1.34 [b]
120	Artificial	9.16±1.45 [a]	231.50±5.37 [a]
	Natural	9.54±1.75 [a]	228.24±11.04 [a]

Values followed by different letters within a column are significantly different at $P < 0.05$.

4. Conclusions

Artificial ripening hastened the time to ripeness of durians (3 days after treated with ethephon). Maturity stage is a main factor affecting quality of durians after both natural and artificial ripening approaches. The fruits harvested at 90% maturity (120 DAA) after both natural and artificial ripening had physicochemical quality close to the fruits which had ripened on the tree (130 DAA fruits). The fruits harvested at 80% maturity (110 DAA) had lower quality than the fruits harvested at 85% maturity (115 DAA) and 90% maturity (120 DAA) , especially after artificial ripening, as seen in low contents of carotenoids, SSC, TSC and antioxidants. Moreover, the fruit ripened using the artificial ripening approach had firmer pulp than naturally ripened fruits. The starch content of naturally ripened 110 and 150 DAA fruits was lower than that of artificially ripened fruits. Antioxidant activities of the fruits were positively related to maturity stage increase and the highest antioxidant activity was found in the fruits left to ripen on the tree. Artificial ripening produced lower antioxidant levels in durians compared to natural ripening, especially in fruit harvested at 80% and 85 % maturity. The results suggested that the fruit at 90% maturity had quality after natural and artificial ripening that was similar to the quality of the fruit ripened on the tree. The fruit at 85 % maturity had higher overall quality than the fruit at 80 % maturity after ripening.

5. Acknowledgements

We would like to thank National Research Council of Thailand for financial support for this project.

References

[1] Zhou, X., Wu, H., Pan, J., Chen, H., Jin, B., Yan, Z., Xie, L. and Rogers, K.M., 2021. Geographical traceability of south-east Asian durian: A chemometric study using stable isotopes and elemental compositions. *Journal of Food Composition and Analysis*, 101, 103940, https//doi.org/10.1016/j.jfca.2021.103940.

[2] Siriphanich, J., 2011. Durian (*Durio zibethinus* Merr.). In: E.M. Yahia, ed. *Postharvest Biology and Technology of Tropical and Subtropical Fruits*. Oxford: Woodhead Publishing, pp. 80-116.

[3] Datepumee, N., Sukprasert, P., Jatuporn, C. and Thongkaew, S., 2019. Factors affecting the production of export quality durians by farmers in Chanthaburi province, Thailand. *Journal of Sustainability Science and Management,* 14(4), 94-105.

[4] Pakcharoen, A., Tisarum, R. and Siriphanich, J., 2013. Factors affecting uneven fruit ripening in "Mon-thong" durian. *Acta Horticulturae*, 975, 329-333.

[5] Maninang, J., Wongs-Aree, C., Kanlayanarat, S., Sugaya, S. and Gemma, H., 2011. Influence of maturity and postharvest treatment on the volatile profile and physiological properties of the durian (*Durio zibethinus* Murray) fruit. *International Food Research Journal*, 18(3), 1067-1075.

[6] Ketsa, S., 2018. Durian- *Durio zibethinus*. In: S. Rodrigues, E. de Oliveira Silva and E.S. de Brito, eds. *Exotic Fruits: Reference Guide*. London: Academic Press, pp. 169-180.

[7] Cheyglinted, S., 1993. *Effect of Ethephon on the Physio-chemical Changes during the Ripening of 'Chanee' Durian (Durio zibethinus Murray) Harvested at Different Maturity Stages.* M.S. The University of Philippines, Philippines.

[8] Thongkum, M., Imsabai, W., Burns, P., McAtee, P.A., Schaffer, R.J., Allan, A.C. and Ketsa, S., 2018. The effect of 1-methylcyclopropene (1-MCP) on expression of ethylene receptor genes in durian pulp during ripening. *Plant Physiology and Biochemistry*, 125, 232-238.

[9] Kulkarni, S.G., Kudachikar, V.B. and Keshava Prakash, M.N., 2010. Studies on physico-chemical changes during artificial ripening of banana (*Musa* sp.) variety "Robusta". *Journal of Food Science and Technology*, 48(6), 730-734.

[10] Sarananda, K.H., Kumari, U.N.G.C., Eeswara, J.P. and Rathnayaka, R.M.N.D., 2004. Artificial ripening to reduce postharvest losses of avocado. *Tropical Agricultural Research and Extension*, 7, 144-149.

[11] Kunjet, S., Sangwanangkul, P. and Siripanich, J., 2002. Effects of ethephon on development and quality of durian fruit cv. 'Monthong' after harvested. *Agricultural Science Journal*, 33(6 Suppl.), 40-44.

[12] Kirk, J.T.O., 1968. Studies on the dependence of chlorophyll synthesis on protein synthesis in *Euglena gracilis*, together with a nomogram for determination of chlorophyll concentration. *Planta*, 78, 200-207.

[13] Association of Official Analytical Chemists, 1984. *Official Methods of Analysis*. 14th ed., Washington: The Association Washington, D.C.

[14] Miller, G.L., 1956. Use of dinitrosalicylic acid reagent for determination of reducing sugar. *Journal of Analytical Chemistry*, 31, 426-428.

[15] Brand-Williams, W., Cuvelier, M.E. and Berset, C., 1995. Use of free radical method to evaluate antioxidant activity. *LWT - Food Science and Technology*, 28, 25-30.

[16] Benzie, I.F.F. and Strain, J.J., 1996. The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": the FRAP assay. *Analytical Biochemistry*, 239, 70-76.

[17] Wisutiamonkul, A., Promdang, S., Ketsa, S. and van Doorn, W.G., 2015. Carotenoids in durian fruit pulp during growth and postharvest ripening. *Food Chemistry*. 180, 301-305.

[18] Wisutiamonkul, A., Ampomah-Dwamen, C., Allan, A.C. and Ketsa, S., 2017. Carotenoid accumulation and gene expression during durian (*Durio zibethinus*) fruit growth and ripening. *Scientia Horticulturae*, 220, 233-242.

[19] Wisutiamonkul, A., Ketsa, S. and van Doorn, W.G., 2015. Endogenous ethylene regulates accumulation of α- and β-carotene in the pulp of harvested durian fruit. *Postharvest Biology and Technology*, 110, 18-23.

[20] Ketsa, S. and Daengkanit, T., 1999. Firmness and activities of polygalacturonase, pectinesterase, β-galactosidase and cellulase in ripening durian harvested at different stages of maturity. *Scientia Horticulturae*, 80(3-4), 181-188.

[21] Palapol, Y., Kunyamee, S., Thongkhum, M., Ketsa, S., Ferguson, I.B. and van Doorn, W.G., 2015. Expression of expansin genes in the pulp and the dehiscence zone of ripening durian (*Durio zibethinus*) fruit. *Journal of Plant Physiology,* 182, 33-39.

[22] Ketsa, S. and Daengkanit, T., 1998. Changes in softening enzymes of durian fruit ripening. *Acta Horticulturae*, 464, 451-454.

[23] Añabesa, M.A., Oria, A.V., Esguerra, E.B. and Sarcos, M.A., 2006. Postharvest behavior and storage life of 3 durian cultivars with varying maturity, waxing and temperature. *Philippines Journal of Crop Science*, 31(1), 29-46.

[24] Haruenkit, R., Poovarodom, S., Vearasilp, S., Namiesnik, J., Sliwka-Kaszynska, M., Park, Y.-S., Heo, B.-G., Cho, J.-Y., Jang, H.G. and Gorinstein, S., 2010. Comparison of bioactive compounds, antioxidant and antiproliferative activities of Mon Thong durian during ripening. *Food Chemistry*, 118(3), 540-547.

[25] Joshi, H., Kuna, A., Lakshmi, M.N., Shreedhar, M. and Kumar, A.K., 2017. Effect of stage of maturity, ripening and storage on antioxidant content and activity of *Mangifera indica* L. var. Manjira. *International Journal of Food Science and Nutrition,* 2(3), 1-9.