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Effect of low temperature storage on quality and total phenolics of Thai eggplant (*Solanum melongena* cv. Gelatik)

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Abstract

In Indonesia, Thai eggplant is one of indigenous vegetables mostly in West Java, which is consumed in “baby” stages and fresh condition as ready-to-serve vegetable. Thai eggplant is rich of phenolics as antioxidant. Low temperature storage is commonly method in extending shelf life of vegetables. However, there is no study related on the effect on low temperature storage on the quality changes in Thai eggplant. The aim of this study was to analyze the effect of low temperature storage on quality and total phenolics of Thai eggplant. Sample of vegetables in the same shape and ripening stage were harvested, sorted, washed, dried and selected sample stored in low temperature storage at 5±1, 10±1, 15±1°C and RH 90-95% for 18 days. The results show that highest weight loss and changes in firmness occured at 15°C, whereas value of yellowness to blueness (b value) in all treatment increased. Highest lightness reduction on flesh happened at 5°C (15.58%), and highest chilling injury of flesh and seed at 5°C. Flesh browning at 4th day for those sample of vegetables stored at 5 and 10°C. Highest and the most rapid chilling injury index increasing at 5°C, Thai eggplant was more sensitive to chilling injury symptoms. Total phenolics decreased significantly during 18 days storage, and vegetables were stored at 10°C could maintain total phenolics better than other low temperatures. Thai eggplant was suggested to store at 10°C as the best low temperature.

Introduction

Eggplant (*Solanum melongena* L.) is a tropical vegetable and has different shapes, sizes and colours, depending on the cultivar. Eggplant is a vegetable which has short shelf life because of water losses and deteriorative physical changes (Jha and Matsuoka, 2002). Eggplant should be stored in low temperature at 10-16°C, RH 90-95% (Boyer and McKiney, 2013). Chilling injury and browning was found in eggplant cv. Money Maker No. 2 stored at 0 and 5°C at 5th and 9th day (Concellon *et al.*, 2004). Besides, lightness reduction, oxidation potential and ultrastructure tissue damage was found in eggplant cv. Money Maker No. 2 that was stored at 0°C (Concellon *et al.*, 2007). Storage temperature affected physical quality in several eggplant cultivars.

Effect of low temperature storage for several eggplant cultivars has been reported in previous study (Concellon *et al.*, 2007; Gajewski *et al.*, 2009; Concellon *et al.,* 2012), but the effect on physical quality of Thai eggplant has not been evaluated, it will be the novelty of this research. This research also clarified the appropriated temperature for Thai eggplant, previous research (Boyer and McKiney, 2013) just reported estimated temperature for eggplant in generally. Thai eggplant has different physical characteristics with another eggplant, thus it will be required different postharvest handling.

The best climatic conditions to grow Thai eggplant are; altitude approximately 1000-2000 meters above sea level; optimum temperature are 23°C at daylight and 17°C at night; netral soil acidity or 5-7; suitable soil type are sandy clay, clay, or rich of humus and microorganism with sufficient water supply; humidity 65-80% and rainfall 800-1200 mm/year. In Indonesia, Thai eggplant is one of indigenous vegetables especially in West Java, which is consumed in “baby” stages and raw condition as ready-to-serve vegetable. Thai eggplant has a potential as natural antioxidant source, with total phenolics content dominates Thai eggplant antioxidant capacity (20.49 mg CAE/ g of dry sample), compared with chlorogenic acid, total anthocyanins and ascorbic acids content (Medina *et al.*, 2014).

Phenolic compounds of fruits and vegetables contribute to antioxidant intake and are presumed to have a health protective action in humans (Pennycooke *et al.*, 2005). Total phenolics as antioxidant can scavenge radicals by inhibiting, initiating and breaking propagation chain or suppressing formation of free radicals by binding to the metal ions, reducing

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hydrogen peroxide, and quenching superoxide and singlet oxygen. So they are supposed to have an important role in the prevention of diseases (Du *et al*., 2009).

Besides afftecting physical quality of several eggplant cultivar, low temperature storage also affects total phenolics alteration. In some cases, after long term storage, large losses (e.g. 50%) of soluble phenolic antioxidants in eggplant was occured in the abscense of browning (Concellon *et al.,* 2012). In other cases, cold storage conditions significantly increase total phenolics content and this can cause some changes in phenol metabolism during storage (Tavarini *et al.*, 2008). Decreasing in phenolic antioxidants content during storage has been shown to be related with browning reactions (Massolo *et al*., 2011). The aim of this study was to analyze the effect of low temperature storage on quality and total phenolics of Thai eggplant, and determine the best temperature for Thai eggplant storage.

Material and Methods

Sample preparation

Thai eggplants (*Solanum melongena* L. cv. Gelatik) with same shape approximately 6 cm in diameter and ripeness stage were harvested (90^{th} day after cultivation) from Agribussiness Farm in Cianjur, Indonesia. Eggplants were sorted, washed with tap water, dried and randomly divided into 3 groups for each temperature storage period. Samples were placed into plastic basket (43.5x32.5x13 cm) and stored in refrigerator with temperature 5±1, 10±1, 15±1°C, RH 90-95% for 18 days.

Weight loss

Weight loss measurement was conducted according to the method by Concellon *et al*. (2012). Individual sample was weighed at the beginning of the experiment and during storage period. Weight loss (WL) was calculated as follows:

$$WL=100\times(Wi-Wf)/Wi \quad (1)$$

where Wi is the initial sample weight and Wf is the final sample weight. Results were expressed as percentage of weight loss and standard deviation from three replications. Nine same Thai eggplants were evaluated for each determined temperature and storage time.

Firmness

Firmness was measured following the method by Massolo *et al.* (2011), using a rheometer (35-12-208, Japan) with a 5 mm flat probe. Each sample was pressed for 50 mm at the equatorial zone with a rate of 30 mm/s, and the maximum force developed during the test was recorded. Three measurements were conducted for each temperature for each storage time. Results were expressed in Newton (N).

Determination of peel color

The color of eggplant peel was measured by a chromameter (Konica Minolta CR-400, Japan) following method by Hung *et al.* (2011). The measurements were expressed as L values (dark to light), parameters a and b represent redness to greenness and yellowness to blueness, respectively. Three readings were taken from three points that were marked on samples. Nine random sampels were used for each measurement.

Flesh browning

Flesh browning was measured folllowing the method by Concellon *et al*. (2007) with slight modification. A Chromameter (Konica Minolta CR-400, Japan) was used to determine the lightness of flesh by parameter L (0 = black and 100 = white). A 0.5cm wide cross-section was excised from the central section whose flesh colour was rapidly measured. Results were expressed as L0, as the mean of three samples per storage time and temperature. It was observed that L0 value of whitish good quality flesh was ≥76, while seed browning showed L_0 values between 71 and 72, an incipient flesh and seeds browning showed L_0 values near 68, and severe flesh and seeds browning implicate L0 values ≤63 (Concellon *et al*., 2007).

Oxidation potential (ΔL)

The oxidation potential was estimated using the Concellon *et al.* (2007) method, with slight modifications. A Chromameter (Konica Minolta CR-400, Japan) was used to measure the colour parameter L on a slice obtained as described recently. Colour was measured immediately after cutting (L_0) and after 30 mins (L_{30}). The oxidation potential was calculated using Equation 2, all measurements were means of three samples per storage time and temperature

$$\Delta L = L_0-L_{30} \quad (2)$$

Chilling injury index (CII)

CII was determined by following the Concellon *et al.* (2005) method. Every two days, 10 samples for each temperature were evaluated by using a numerical scale from 1 to 5. The CII was calculated according to the following Equation 3.

$$CII = \sum(ni\ x\ i)/N. \quad (3)$$

Where *ni* is the number of Thai eggplant receiving the mark '*'i"* (from 1 to 5) and *N* is the total number of Thai eggplant. The numerical scale represents: 5, severe damage; 4, moderate damage; 3, regular damage; 2, low damage; 1, no damage.

Total phenolics content

Total phenolics content was determined by following Zaro *et al.* (2014) method. One gram of frozen flesh was ground in a miller and added to 20 mL ethanol. The suspension was vortexed, extracted during 30 mins and then centrifuged at 12,000 × g for 10 mins at 4°C using centrifuge (Eppendorf AG 22331, Germany). For total phenolics determination, 50μL of Folin–Ciocalteu reagent were diluted with water by ratio 1:1 ratio and then pipetted into test tubes containing 350 μL ethanolic extracts and 500 μL water. After 3 mins, 100 μL 20% Na_2CO_3 (Merck, Germany) in NaOH (Merck, Germany) 0.1 mol/L and 1.5mL distillated water were added. The reaction mixture was vortexed and then incubated for 90 mins. The absorbance was measured at 760 nm using spectrophotometer (Hitachi U-2900, Japan) and phenolic compounds content was calculated using tanat acids (Merck, Germany) as a standard. Two extracts were prepared for each temperature and measured in triplicate. Results were expressed in mg tanat acid equivalent/100g fresh matter (mg TAN/100 g fm). Total phenolics was analyzed before and after storage time.

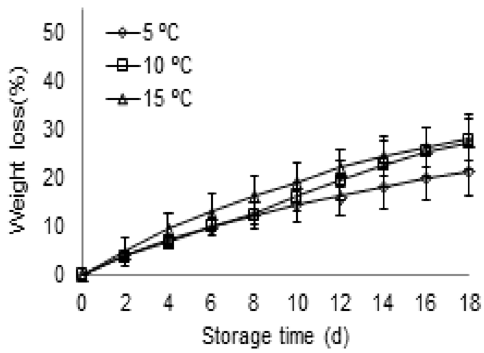
Statistical analysis

A factorial design was built in defining storage temperature (3 levels) and storage time (10 levels) as factors for all parameters, except for total phenolics use 2 levels for storage time. The data obtained were analyzed using Analysis of Variance (ANOVA) to determine the effect of treatment and analyzed with Duncan Multiple Range Test (DMRT) to determine the significance differences of each treatment at 95% confidence level.

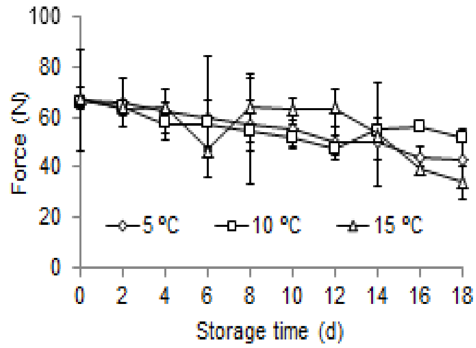
Results and Discussion

Weight loss

The effect of low temperature storage on weight loss showed in Figure 1A. Low temperature at 5, 10 and 15°C significantly affected percentage of weight loss by 12.7%, 14.71% and 16.64% ($p \leq 0.05$). Weight loss was generally increased during 18 days storage



A



B

Figure 1. Changes in weight loss (A) and firmness (B) during 18 days storage at 5, 10 and 15°C of Thai eggplant

at 5, 10 and 15°C, which the higher weight loss rate happened on 15°C storage temperature. Eggplant cv. Ryoma experienced weight loss 25.47% during 6 days storage at 15°C RH 90% (Jha and Matsuoka, 2002).

Thai eggplant weight loss was caused by transpiration process, which transfered water vapor from the surface to the surrounding air. Transpiration occurs when there is a gradient of water vapor pressure between the tissue and the surrounding air (Hung *et al.*, 2011).

Firmness

Firmness is one of freshness indicators and important to be analyzed in this study, because Thai eggplant is usually consumed as ready-to-serve vegetable that is consumed in fresh condition. Firmness was affected by weight loss, where the higher weight loss resulted the lower firmness. Thai eggplant firmness was not affected significantly by low temperature storage, was presented in Figure 1B.

Thai eggplant firmness significantly decreased after 18 days storage at 15°C ($p \leq 0.05$), it was stored at 5°C and 10°C did not show significant changes ($p \geq 0.05$) after storage. Thai eggplant firmness at 15°C at before storage was 67.20 N and significantly decreased to 46.99N at 6th day during storage, but

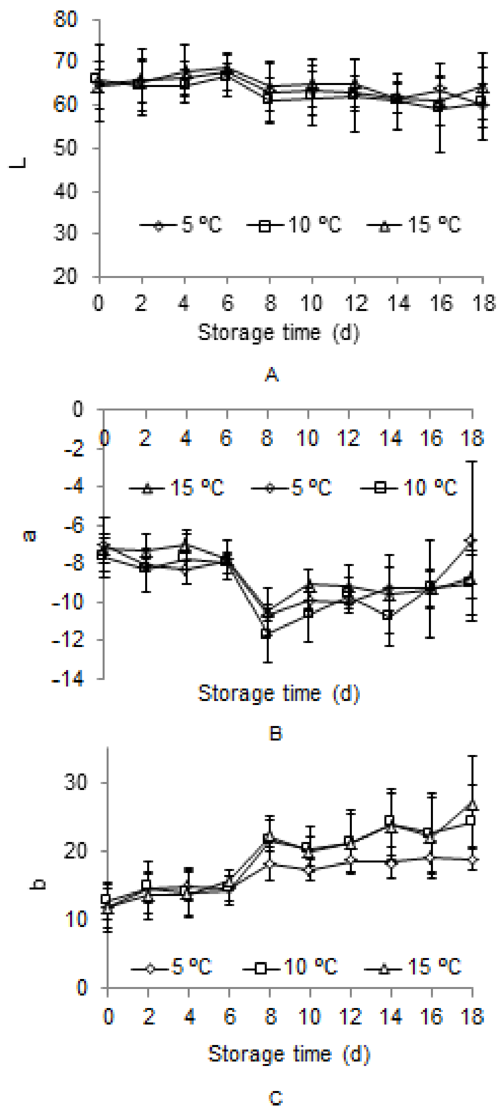


Figure 2. Changes in L (A), a (B) and b (C) value during 18 days storage at 5, 10 and 15°C of Thai eggplant

significantly yet temporarily increased in 12th day during storage to 63.47N ($p \leq 0.05$). Those temporarily increase was may caused by wrinkled peel that caused the peel was tougher than before. Firmness temporarily increasing in eggplant cv. Ryoma which stored at 20 and 30°C which was caused by rotting process, and the epidermis probably lost its firmness and there was the inner surface that resisted the compression (Jha and Matsuoka, 2002). Firmness decreased dramatically at the end of storage and it indicated deterioration process.

Peel color

Change of L, a and b during storage, shown in Figure 2. L, a and b values were significantly not affected by low temperature storage. Storage time also significantly not affected on L and a value, but significantly effected the increased on b value ($p \leq 0.05$). The value at beginning of the storage for

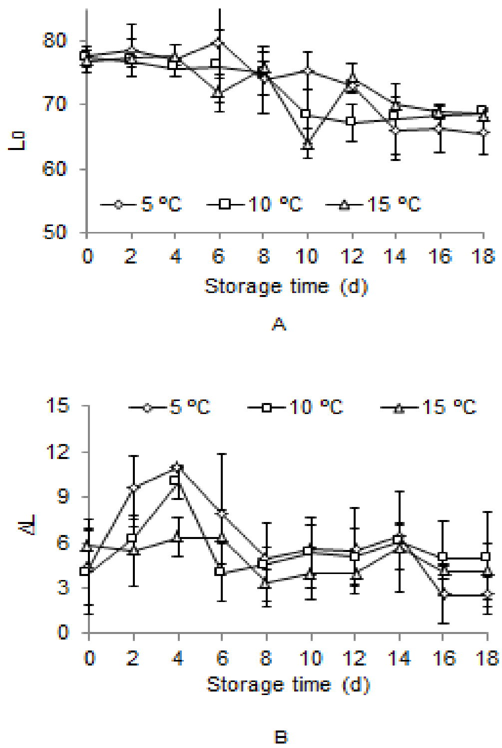


Figure 3. Changes in L_0 (A) and ΔL (B) during 18 days storage at 5, 10 and 15°C of Thai eggplant

low temperature 5, 10 and 15°C was 11.77, 12.63, 11.71 and at the end storage the value is 18.70, 24.08, 27.16, respectively. b value showed yellowness of Thai eggplants peel, its increasing was caused by peel color changing from green to yellow during deterioration process. The colour parameters significantly not affected by the storage but by differences of cultivars (Gajewski *et al.*, 2009). Storage time not affected a and b value of eggplant cv. Chikuyo, but significantly affected the decreasing of L value (Hung *et al.*, 2011).

Flesh browning

Flesh browning and seed is less common chilling injury symptoms. Seed browning occurs in some species in the Solanaceae (Concellon *et al.*, 2005). Flesh Browning presented by L_0 value and was not significantly affected by low temperature ($p \geq 0.05$) as shown in Figure 3A. Otherwise storage time significantly decreased browning in flesh and seed ($p \leq 0.05$). L_0 value at initial storage for low temperature 5, 10 and 15°C (77.64, 77.41, 76.83, respectively) decreased at the end storage (65.54, 68.74, 68.65, respectively).

Lightness of flesh and seed eggplant cv. Lucia decreased during 21 days storage at 10°C (Concellon *et al.*, 2012). Lightness reduction value on flesh was higher at low temperature 5°C (15.58%) than at 10 and 15°C (11.2%, 10.64%, respectively). It was estimated that chilling injury of flesh and seed happened at 5°C, which marked by black seed and palidness on flesh.

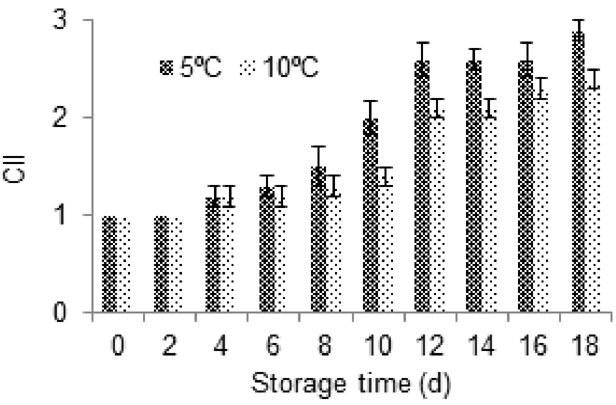


Figure 4. Changes in chilling injury index during 18 days storage at 5 and 10°C of Thai eggplant

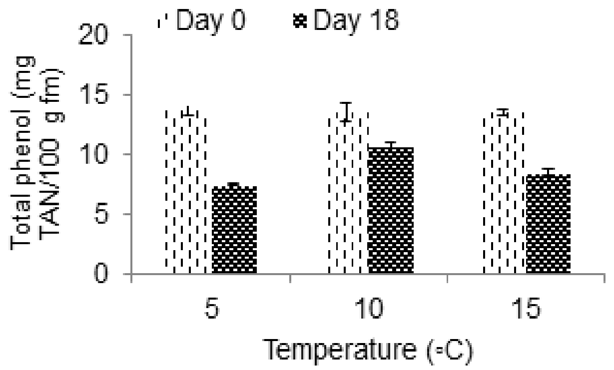


Figure 5. Changes in total phenol at beginning and end of storage at 5, 10 and 15°C of Thai eggplant

Oxidation potential (ΔL)

Oxidation potential was another parameter to detect flesh browning. Fruits with cold-induced browning do not experience further browning after being sliced (Concellon *et al*., 2007). Low temperature and storage time significantly not affected on ΔL ($p \geq 0.05$) as shown in Figure 3B. In a previous study (Concellon *et al*., 2007) ΔL decreased gradually until 6th day and thereafter remained mostly constant during storage either at 10°C. Different result in this study showed that ΔL increased dramatically at 4th day then dropped at 8th and 6th day at 5 and 10°C respectively, thereafter it remained constant until the end storage time. It was indicated that beginning of flesh browning occured at 4th day at 5 and 10°C, respectively.

ΔL at 15°C decreased sharply at 8th day, thereafter remained mostly constant until the end of storage time. Declining of ΔL was caused by reduction of enzyme polyphenol oxidase (PPO) activity, the enzyme activity decrease after browning, hence ΔL value remained constant thereafter. Similar results were previously reported by Concellon *et al*. (2004), the enzyme PPO activity in eggplant cv. Money Maker No. 2 was found to decrease with time after browning.

Chilling injury index

There was no CI symptoms were found in Thai eggplant stored at 15°C, while CI symptoms were observed during storage 5 and 10°C (Figure 4). CII of Thai eggplant stored at 5 and 10°C changed after 4 days of storage (CII = 1.2), the effect was marked by the presence of black spot on the peel. CII increased gradually in storage at 5 and 10°C till the end of storage, CII increased more rapidly and higher at 5°C than at 10°C. The previous study reported no CI symptoms was found in eggplant cv. Money Maker stored at 10°C (Concellon *et al*., 2004). According this study Thai eggplant more sensitive toward CI symptoms. It was expected because Thai eggplant was harvested in "baby" or unripe stage. Thai eggplant was commonly consumed in "baby" stage as ready to serve vegetable. The previous study showed that eggplant which was harvested in "baby" stage was more sensitive to deterioration process (Zaro *et al.,* 2014). Harvesting riper fruit, with well-developed sugar profiles, would reduce damages which is caused by chilling injury due to lower temperature (Beckles, 2012).

Total phenolics

Eggplants are particularly rich of antioxidant compounds which have been linked to various health benefits (Concellon *et al.*, 2012). Such as peel anthocyanins, pulp carotenoids, ascorbic acid, phenolics and chlorogenic acid (Zaro *et al*., 2014). Total phenolics dominate antioxidant content in eggplant (Gajewski *et al*., 2009). Generally, phenolics content may either increase or decrease in fruits and vegetables depending on the storage conditions (Tavarini *et al.*, 2008) especially the storage temperature. During 21 days of storage at 10oC, phenolics increased in eggplant cv. Lucia (Massolo *et al.*, 2011), same result has been reported that total phenolics in eggplant peel increased after storage (Gajewski *et al*., 2009). But total phenolics in harrow diamond peaches decreased gradually after 6 days storage at 2[1]°C (Tsantili *et al.*, 2010).

In this study, low temperature and storage time significantly affected on total phenolics in Thai eggplant (Figure 5). After 18 days storage, the total phenolics decreased 45.69, 21.66 and 37.09% at 5, 10, 15°C respectively, but those were stored at 10oC could maintain total phenolics better than others. Previous study (Concellon *et al*., 2012) reported that high phenolics loss (e.g. 50%) after longterm storage in eggplant cv. Lucia can occur with the absence of browning. This study showed different result that largest total phenolics loss at low temperature 5°C followed by highest browning value. The phenolics loss during storage has been related with browning reaction (Massolo *et al.,* 2011). The decrease of total phenolics during storage is attributed to polyphenol oxidases (PPOs) and peroxidases (PODs)-catalyzed oxidation of phenolic compounds. PPOs catalyze the oxidation of phenolics to quinones using oxygen as a final electron acceptor, while for peroxidases the final electron acceptor is hydrogen peroxide. After quinone formation, secondary non-enzymatic reactions result in the accumulation of melanin-like pigments, giving a brown undesirable appearance to the tissues.

Thai eggplant is usually consumed as ready to serve vegetable which is consumed in fresh condition. It was expected to maintain phenolics as antioxidant, because processing and cooking potentially decreased eggplant's antioxidant (Zaro *et al.*, 2015).

Conclusion

Low temperature storage significantly affected on weight loss, firmness, CII, and total phenolics. Thai eggplant was suggested stored at 10^{o}C, it was better to maintain from chilling injury and maintain total phenolics better than others with lowest reduction value 21.66%. Storage temperature 5 and 15^{o}C were not appropriate for Thai eggplant storage, although previous study reported that eggplant should be stored at 10-15^{o}C.

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