

Effect of Light and Temperature on the Quality of Sam-Pee Mango (*Mangifera Indica*) Juice

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Abstract. Mango juice is rich in vitamins, carotenoids and polyphenols. The effects of temperature and fluorescent light during processing and storage affected the carotenoids content in juice. This study was aimed to evaluate the effects of these two effects on carotenoids and other chemical properties of Sam-pee mango juice filled in clear bottle during commercial handling. It was conducted by comparing the changes which were exposed to fluorescent light and dark room at different temperatures. The carotenoids content in mango juice exposed to light at room temperature was significantly lower than those stored in the dark. The storage temperature higher than 35°C caused rapid deterioration of carotenoids and color. It was found that the smallest changes occurred during storage at 4°C. The refrigeration storage and ascorbic acid supplement provided juice with significantly higher in the amount of β -carotene and total carotenoids and less color changes in comparison with the other samples after stored for 24 weeks.

Keywords: Mango juice; temperature; fluorescent light; ascorbic acid; β -carotene; carotenoids

1 Introduction

The Sam-pee variety of mango is a local variety grown in the Northern part of Thailand. It can be grown in many types of soil and resists the harshness of the climate. The trees are growing from seed and it takes about 3 years for them to bare fruits. This variety is very productive but the fruits are small in size. The ripe fruits are of yellow color with a strong and pleasant aroma. The pulp of Sam-pee mango contains abundant juice. These characteristics are suitable for mango juice processing recommended by Yoonchalad *et al* [1].

Mango juice has been used as a convenient substitute for fresh fruits. Mango juice has high nutritive value with its rich vitamins, carotenoids, minerals, and polyphenols [2]. Mango juice is a good source of potassium but low in the amount of sodium. The mango juice is a rich source of antioxidants, due to the presence of high amount of carotenoids and polyphenols [3]. The carotenoids are pigments that provide orange or red color in plant tissues. They are reported as precursors in the synthesis of vitamin A. The β -carotene, which is one of carotenoids, also functions as an antioxidant and prevents the occurrence of free radicals [4]. The carotenoid content of mango juice was studied by a number of researchers. The study by Veda *et al.* [5] showed that β -carotene content in ripe mango ranged from 0.55 ± 0.03 mg/100 g in the Malgoa variety to 3.21 ± 0.25 mg/100 g in the Badami variety. Bioaccessibility of β -carotene ranged from 24.5% in Badami to 39.1% in Raspuri varieties of mango. The carotenoid content of mango juice depended on the degree of ripening of the fruits selected and processing [6, 7]. The mixing and blending were required when small batches could be prepared. The ascorbic acid content in the juice after processing was differently reported. The low content of ascorbic acid, 2.5mg/100g, was found in USDA National Nutrient Database for standard Reference while 12.57 mg/100ml was reported in commercial mango juice from Iran [8].

The carotenoids are sensitive to heat and light. Fratianni *et al.* [9] reported that almost all carotenoids in orange juice were decreased by about 50% when heated at 85°C for 1 min of Microwave heating. The heating process for preservation of the mango juice could destroy the carotene. Chen *et al.* [10] reported that β -carotene can be changed by either isomerization from trans-isomer which is normal form into cis-isomer or oxidative degradation to form volatile compounds influencing the color change.

Montgomery and Petropakis[11] also reported that the mango juice quality was changed by polyphenoloxidase resulting in change from bright yellow to dark yellow color. The color change during storage of fruit juice can be prevented by heat inactivation [12] and some food additives such as potassium metabisulfite, sodium metabisulfite, butylated hydroxy anisole (BHA), butylated hydroxy toluene (BHT), sorbic acid, and ascorbic acid [13]. Benjamin [14] reported that the stable color of peach juice occurred by adding ascorbic acid together with sulfite compounds.

The mango juice has advantages as rich in pro-vitamin A activity and antioxidant capacity. The degradation of carotenoids by oxidation is alleged to affect the mango juice quality. The quality of mango juice during storage has been scarcely reported in the recent past. The storage and handling conditions influenced by the wholesalers and retailers affected the quality of the juice. Post-processed juice could possibly be handled under some conditions affected the stability of carotenoids. During display, the mango juice might be exposed to the light, especially the fluorescent light. High temperature storage might happen, during the warehouse storage or on the shelf. The storage temperature in the midday in some places might reach 45°C or higher. In a retail store, it might be displayed in a refrigerator (4°C) or in a room condition (27-30°C). This study was aimed to evaluate the effects of fluorescent light and temperature on carotenoids and some chemical properties of Sam-pee mango juice during commercial handling.

2 Materials and Methods

2.1 Preparation of Mango Juice

Mango fruits, Sam-pee variety, were harvested from the plantation of the Agricultural Technology Research Institute, Lampang, Thailand. The fruits with specific gravity 1.00-1.015 were chosen to ripe by aging with sodium carbide in a cardboard box. The pulp of ripe mangoes was blended and added with water to make 25% mango pulp juice. The juice was adjusted with sugar and citric acid to 15°brix and 0.4% TA [17]. The juice was heated to 80-85°C for 5 min, then hot filled into clear glass bottles (250 ml). It was pasteurized again in boiling water for 15 min then cooled to room temperature. The bottled juice was used for further experiments. The color, β -carotene and total carotenoids of mango juices during processing were determined.

2.2 Effect of Fluorescent Light on Mango Juice Quality

An amount of 0.05% of ascorbic acid was added to the juice prior to bottling and heat treatments. The bottled juice without ascorbic acid was kept in cupboards under ambient temperature in a dark environment. In addition, juice without and with 0.05% ascorbic acid, was stored under fluorescent light of 500-600 lux light intensity. They were stored for 24 weeks under ambient condition. The juice samples were randomly picked every 4 weeks and checked for color, ascorbic acid, non-enzymatic browning index, total carotenoids and beta carotene.

2.3 Effect of Storage Temperature on Mango Juice Quality

The bottled mango juice was kept under various temperatures namely $4\pm 2^\circ\text{C}$ (in a refrigerator), ambient temperature (27-30°C in a box) and 45°C (in an incubator). The bottled mango juice with 0.05% ascorbic acid was kept in a refrigerator ($4\pm 2^\circ\text{C}$). They were stored for 24 weeks. The juice samples were checked for color, ascorbic acid, non-enzymatic browning index, total carotenoids, and β -carotene.

2.4 Determination of the Physical and Chemical Components

The juice samples were subjected to color determination using Minolta® CR-300. The color was characterized using (L^* , a^* , b^*) units. The pH was measured with pH meter, Schott CG825. The titratable acidity was determined according to AOAC [18]. The total carotenoids and β -carotene were determined according to Ranganna [19]. The carotenoids from mango juice were extracted using acetone then followed with petroleum ether extraction. Na_2SO_4 was applied to remove moisture from petroleum

ether fraction. The petroleum ether was removed in a rotary evaporator. The solid mass was treated to remove the fatty acid by saponification with 10% KOH in methanol. Then, it was repeated with the petroleum extraction. The solid mass was solubilized. Total carotenoids were determined as the absorption at 453 nm using a spectrophotometer and β -carotene was determined using HPLC equipped with a C18 column and a photodiode array detector. The operation condition was using the mixture of acetonitrile : dichlorometane : methanol (50:30:20) as a mobile phase and flow rate of 1 ml/min. The non-enzymatic browning indexes (NEBI) were determined by the changes in the absorbance at 420 nm [20].

2.5 Statistical Analysis

The design of experiment was a completely randomized design (CRD). All experiments were repeated three times and were reported as the mean \pm standard deviation (\pm SD). Statistical significance of difference between means or between treatments were determined using ANOVA with a significant difference between treatments set at $p < 0.05$ in all cases. The statistical analysis was done using SPSS statistical package version 17.

3 Results and Discussion

3.1 Effects of Fluorescent Light on the Mango Juice Qualities

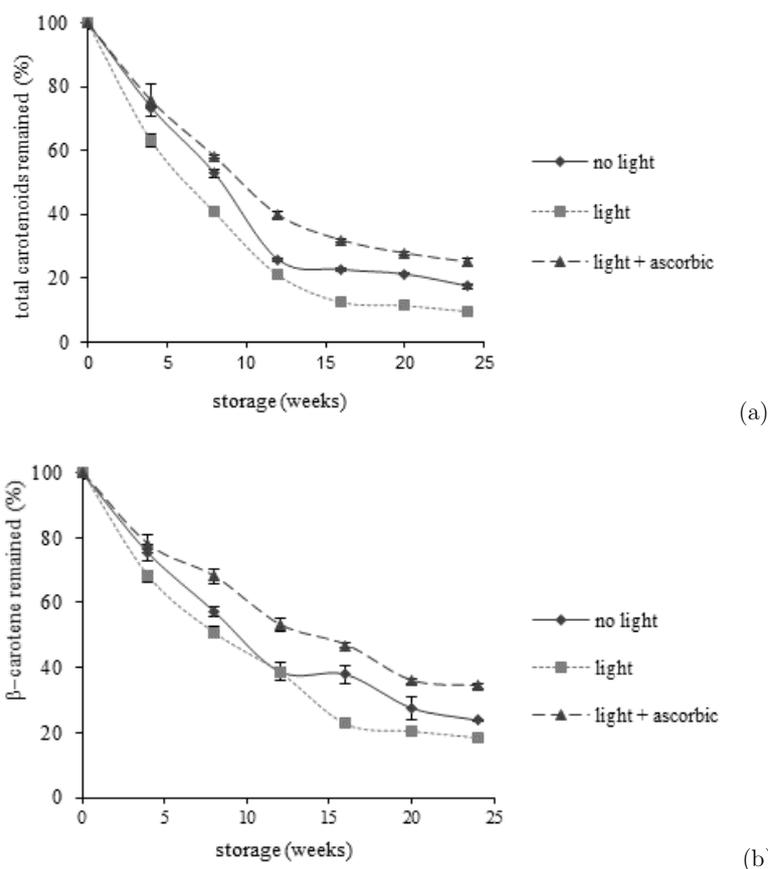


Figure 1. Changes in total carotenoids (a) and β -carotene (b) content of mango juices stored with fluorescent light and absence of light

The processed and bottled Sam-pee juice had characteristics of bright yellow juice with pH 3.47 ± 0.08 , ascorbic acid content of 5.08 ± 0.52 mg/100ml, and total soluble solids of 15.50 ± 0.25 °brix, total

carotenoids of 766.99 ± 19.10 and β -carotene of 452.43 ± 21.50 g/100ml. During storage at ambient temperature, the β -carotene and total carotenoids decreased very rapidly in the first 15 weeks (Fig. 1). The fluorescent light affected the amount of β -carotene and total carotenoids. The juice stored under fluorescent light contained less β -carotene and total carotenoids than those stored in the dark. The juice added with ascorbic acid had β -carotene and total carotenoids levels of 25.00 ± 1.07 and 34.26 ± 0.82 , respectively, while the juice kept in the dark had levels of 23.79 ± 0.35 and $17.54 \pm 0.82\%$ respectively. The addition of ascorbic acid to samples retarded the decrease of both β -carotene and total carotenoids as compared to samples without ascorbic acid added.

Many reports suggest that there were almost 30 types of carotenoids in mango. Among these carotenoids, the β -carotene was the main compound amounting to 30-50% [21]. Each type of carotenoid was affected by the light differently [22, 23]. The degradation of total carotenoids decreased rapidly in first 12-15 weeks of storage. Free radicals were generated from the reactions of the degradation causing a chain reaction. After 12 weeks of storage, the number of the sensitive carotenoids has significantly decreased.

Ascorbic acid content of mango juice gradually decreased in all treatments (Table 1). The ascorbic acid content in juice stored under fluorescent light decreased faster than juice stored in the dark (Table 2). In the juices without ascorbic acid added contained almost no ascorbic acid after 12 weeks. The destruction of ascorbic acid in mango juice during storage was also reported by Falade *et al.* [24].

The NEBI was increased in all conditions. The increasing of the NEBI was slowed during first 12 week storage, but after that it increased rapidly. The NEBI value of juices under fluorescent light was similar to the juice kept in the dark (Fig. 2). The addition of ascorbic acid 0.05% did not slow down the increase of the NEBI in the juice. The NEBI is the result of Maillard reactions and causes color changes and nutrition losses [25]. The end products formed by non-enzymic browning including organic acids, furans, furanones, ketones, cyclopentanones, pyranones and pyrroles, which many of these contributed to off flavor in the juices [26]. Falade *et al.* [24] suggested the b^* value and chroma were main indexes for color changes in mango juice during storage.

The pH of juices decreased during storage. The changes of pH in the juices kept in the dark and fluorescent light were not significantly different ($p > 0.05$). They were in the range of 3.50 to 3.05. This agreed with the report from Alaka *et al.* [27] and Falade *et al.* [24].

Table 1. Ascorbic acid content in the mango juices during 24 week of storage under fluorescent light and absence

Weeks	Ascorbic acid content (mg/100 ml)		
	Dark	Fluorescent light	Ascorbic acid added/ fluorescent light
0	$5.54^a \pm 0.03$	$5.56^a \pm 0.04$	$34.97^a \pm 0.33$
4	$4.20^b \pm 0.05$	$2.98^b \pm 0.14$	$33.50^b \pm 0.11$
8	$3.10^c \pm 0.11$	$2.45^c \pm 0.11$	$32.08^c \pm 0.34$
12	$1.08^d \pm 0.11$	$1.06^d \pm 0.08$	$31.76^c \pm 0.11$
16	$0.62^e \pm 0.02$	$0.52^e \pm 0.05$	$30.61^d \pm 0.37$
20	$0.54^e \pm 0.08$	$0.58^e \pm 0.03$	$28.99^e \pm 0.08$
24	$0.44^e \pm 0.09$	$0.62^e \pm 0.05$	$26.24^f \pm 0.34$

Each value is the mean of three replications.

Means, in the same column, with different superscripts differ significantly at $p < 0.05$.

The juice with ascorbic acid added also had reduction of pH, but the changes were slower than those in samples subjected to two other treatments (Fig. 2). This might be because of the addition of ascorbic acid to the juice. It has been reported that an increase in buffer capacity was found when concentration of ascorbic acid increased in the citrate buffer solution [22]. The ascorbic acid slowed the degradation of total carotenoids and β -carotene. The ascorbic acid could compete with the carotenoids in reacting with free radical molecules [23]. The additional of ascorbic acid to the juices slowed also down the changes of pH and amount of non-enzymic browning products. Hansawasdi *et al.* [28] studied on mango juice from *Mangifera indica* Linn. cv. Nahm-dawg-mai recommended the addition of 9% ascorbic acid to prevent deterioration of color.

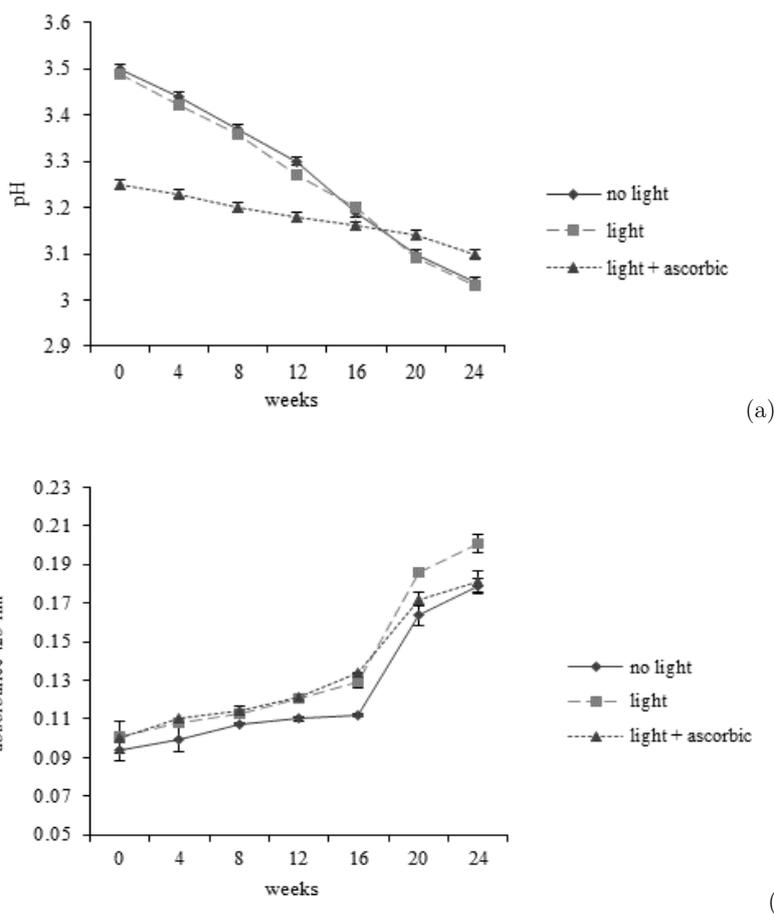


Figure 2. Changes of physico-chemical properties of mango juice, pH (a) and non-enzymic browning (b), stored 24 weeks under fluorescent light and absence of light.

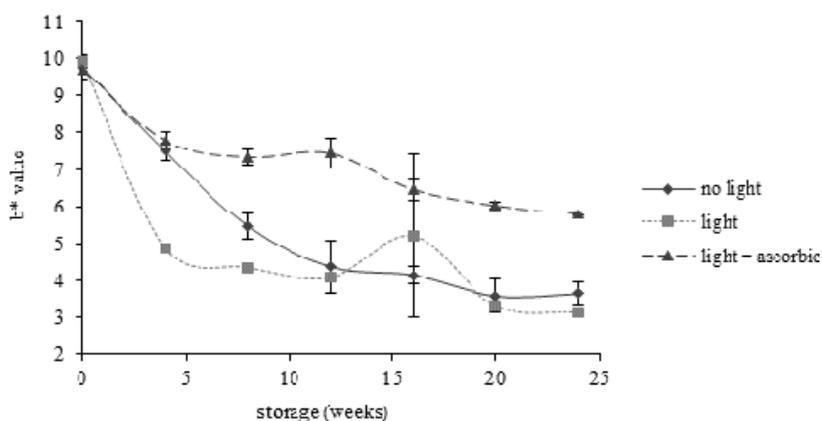


Figure 3. Changes of the yellowness (b*) of mango juice stored under fluorescent light

The color of juice stored under experimental conditions has not undergone a noticeable change under any of the treatments. However, the hue values changed during storage. The yellowish color in juices related to the β -cryptoxanthin and β -carotene [29]. The juices without ascorbic acid added had lightness (L^*) changed from 36 to 32, redness (a^*) changed from -4 to -1.5 and yellowness (b^*) changed from 9.8

to 3.5. The juice with ascorbic acid added shows a lesser change in yellow value than other samples (Figure 3). The lightness and redness were not significantly different in juices subjected to different treatments. That means the juice with ascorbic acid still had the color closer to the initial juice, while the color of the others samples might have become a little darker. The reduction in yellowness (b^* value) or the shift of yellow color toward light brown color related to the increase in NEBI [7]. The changes of color might have been caused by Maillard reaction, carotenoid oxidation and ascorbic acid oxidation [30, 31].

3.2 Effects of Temperature on the Mango Juice Qualities

The storage temperature affected the changes in mango juice quality. The higher temperature storage caused faster changes in chemical composition of juices. The ascorbic acid content in mango juice was depleted to a level lower than 1.0 mg/100 ml after 8, 12 and 16 weeks when stored at 45°C, ambient and 4°C, respectively. The ascorbic acid content of juice remained high in the mango juice added with 0.05% ascorbic acid. This remaining ascorbic acid could prevent the oxidization of the total carotenoids contained in the juices (Table 2). The pH of the juice with added ascorbic acid was stable after 16 weeks of storage (Fig. 4a), while the pH of juice without addition of ascorbic acid changed from 3.5 to less than 3.0 when stored at 45°C.

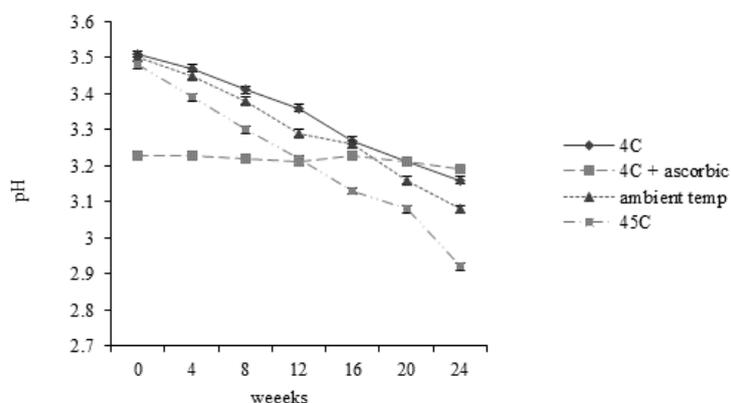
Table 2. Ascorbic acid content (mg/100 ml) in mango juice during 24 weeks storage at different temperatures.

Weeks	Storage conditions			
	4°C	4°C + 0.05% ascorbic acid	Ambient temperature (27-30°C)	45°C
0	4.61 ^a ±0.05	34.56 ^a ±0.13	4.69 ^a ±0.08	4.59 ^a ±0.06
4	3.98 ^b ±0.17	31.47 ^b ±0.49	3.61 ^b ±0.281	3.12 ^b ±0.08
8	3.17 ^c ±0.13	30.42 ^c ±0.37	2.44 ^c ±0.14	1.47 ^c ±0.16
12	2.10 ^d ±0.03	28.73 ^d ±0.81	1.19 ^d ±0.24	0.76 ^d ±0.02
16	1.51 ^e ±0.17	27.85 ^{d,e} ±0.27	0.80 ^e ±0.08	0.50 ^e ±0.01
20	0.52 ^f ±0.01	27.45 ^e ±0.24	0.68 ^{f,g} ±0.04	0.24 ^f ±0.06
24	0.42 ^g ±0.06	24.61 ^e ±0.50	0.63 ^{f,g} ±0.06	0.16 ^g ±0.03

Each value was the mean for three replications.

Means, in the same column, with different superscripts were significantly different at $p < 0.05$.

The NEBI was also affected by the storage temperature. The rapidly increased in NEBI was found in the juice stored at 45°C, while the changes in other condition juices were similarly (Fig. 4b). The results agreed with the report of Lee and Chen [32] that a higher incidence of non-enzymatic browning reaction was found in the juice stored at higher temperature.



(a)

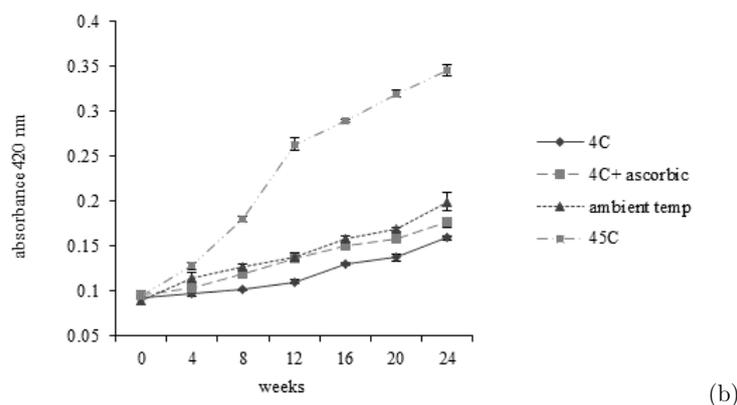


Figure 4. Effects of temperature on physico-chemical properties of mango juice stored under fluorescent light and absence of light for 24 weeks.

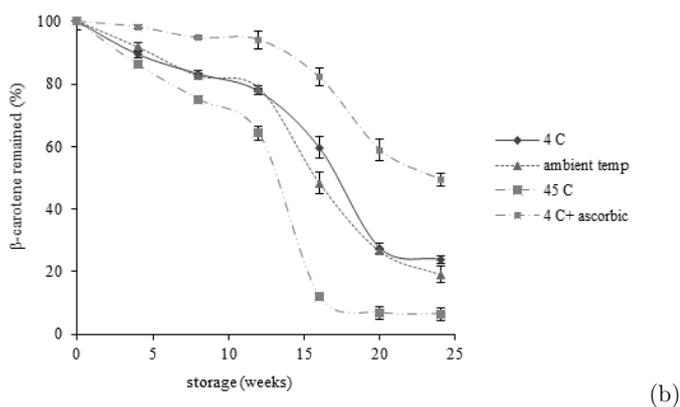
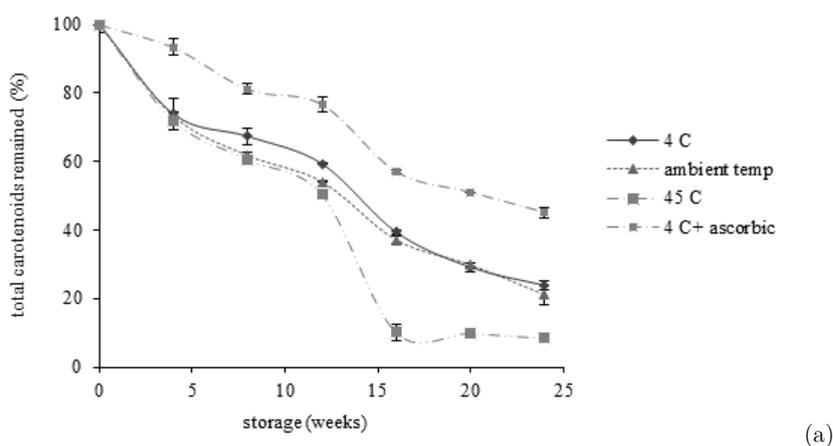


Figure 5. Effects of temperature on total carotenoids (a) and β -carotene (b) in mango juice stored under fluorescent light

The carotenoids content of mango juice were degraded by high storage temperatures. The total carotenoids and β -carotene was remained about 10% within 15 weeks storage under warehouse simulation temperature, 45°C (Fig. 5). The degradation of carotenoids was almost the same in the samples without ascorbic supplemented when stored under refrigeration and ambient conditions. The amount of 20% of total carotenoids and β -carotene were remained in juices after 24 week storage under

4°C and ambient. The addition of ascorbic acid to the juice slowed down the degradation. The remains of the total carotenoids and β -carotene were 50%.

The changes in total carotenoids were faster decreased when storing pasteurized orange juice in the temperature higher than 35°C [33], but a slight decrease was noticed during refrigeration [34]. Our data agreed only in the higher temperature condition. The composition, such as pH, and type or structure of food matrix could be the factors that cause the variation in degradation [35].

The ascorbic acid also retarded the changes of yellowness. The storage at 4°C and ambient temperature were not much different from each other, but the yellowness decreased very fast in samples stored at 45°C (Fig. 6).

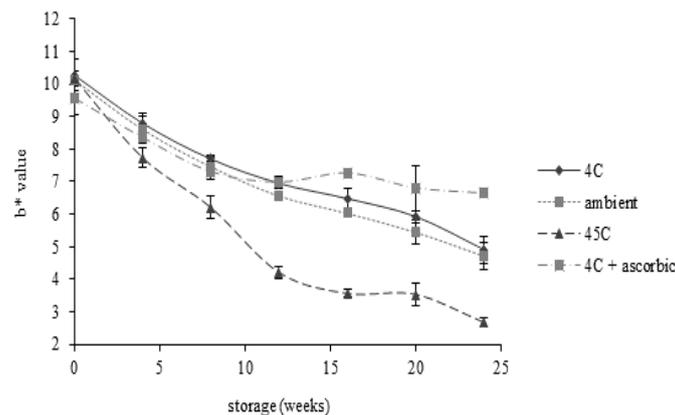


Figure 6. Effects of temperature on the Yellow value (b^*) of the mango juice during storage under fluorescent light

The higher temperature also induced the degradation of β -carotene which agreed with Pesek and Warthesen [36]. The addition of ascorbic acid prevented the depletion of carotenoids significantly when the juice was kept at 4°C and under fluorescent light, which was the preferred condition for keeping the ready-to-drink juice.

4 Conclusion

Our data demonstrated that filling our mango juice in the clear bottles is preferable. The addition of ascorbic acid is necessary to slow down the degradation of carotenoids in mango juice, while storage temperature higher than 30°C should be avoid. The juice can be handled and stored under ambient or refrigeration condition for 15 weeks without lost in bright yellow color appearance and carotenoids content remains higher than 50% of initial amount. The juice can be displayed on the shelf with fluorescent light without speed up the degradation of carotenoids.

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